

XVIII. *On the Muscular and Endoskeletal Systems of Limulus and Scorpio; with some Notes on the Anatomy and Generic Characters of Scorpions.* By E. RAY LANKESTER, M.A., LL.D., F.R.S., Jodrell Professor of Zoology, assisted by W. B. S. BENHAM and Miss E. J. BECK.

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PART I. *Introduction.* By E. RAY LANKESTER.

WHEN, two years ago, I undertook to institute a close comparison of the structure of *Limulus*, on the one hand with that of the Crustacea, and on the other hand with that of the Scorpion and other Arachnida, in order to definitely and fully substantiate the view which for many years had appeared to me plausible, viz. that *Limulus* is no Crustacean, but an Arachnid, I found considerable difficulty, owing to the fact that details concerning the structure both of *Limulus* and of *Scorpio*, in reference to many critical points, were not to be met with in the literature of zoology. In consequence, I have found it necessary to undertake, in conjunction with my pupils, investigations upon various matters connected with the histology and coarser anatomy of both *Limulus* and *Scorpio*, which have yielded remarkable results—remarkable because they were obtained in the attempt to verify a hypothesis, and have uniformly tended to verify it. Thus, I discovered in *Scorpio* an organ which represents the brick-red coxal glands of *Limulus* (Proc. Roy. Soc. 1882), and in the remarkable microscopical structure of these “vascular glands” I have detected a character which connects *Limulus* and the Arachnids in the closest way whilst having no exact equivalent in any Crustacean

(Quart. Journ. Microsc. Sci., January 1884). Further, I investigated the structure of both the simple and the compound (or aggregated) eyes of *Limulus* and of *Scorpio*, and again obtained from the minute microscopic structure evidence of the closest agreement between these two genera and of total divergence from the Crustacea (Quart. Journ. Micr. Sci., January 1883).

Again, since the structure of the genital ducts in Crustacea is simple or, in any case, non-reticulate (except in the male *Apus*), whilst both oviducts and sperm-ducts in *Scorpio* and other Arachnida have the characteristic form of a mesh-work, I requested my pupil Mr. W. B. S. Benham to investigate the structure of the spermatic duct and glands of *Limulus*, hitherto unexplored. Mr. Benham found (and has described in the 'Transactions of the Linnean Society,' 1883) a highly subdivided reticulum, or mesh-work, constituting the spermatic duct, as in the Scorpions. The oviduct had previously been shown by Owen to have essentially the form of a network.

Lastly, I have found (and am about to explain in detail in the Quart. Journ. Micr. Sci.¹) the most intimate agreement between *Limulus* and *Scorpio* in respect of the following points of minute structure:—(1) the blood-corpuscles; (2) the softer connective tissues; (3) the entochondrite (internal sternum of Straus Durkheim), which is, in both cases, a mass of condensed connective tissue with cells of very characteristic appearance, but so like in the two cases as to be practically indistinguishable; (3) the gastric cæca and their lining epithelium.

Amongst the most important points of agreement between *Limulus* and the Arachnids is that insisted upon by Straus Durkheim, namely, the possession of an internal freely suspended sternum or plastron of connective tissue (cartilaginoid tissue), to which numerous muscles are attached. Such an entochondrite exists in no Crustacean²; it probably is more or less closely similar in nature to the so-called "chorda" discovered by Leydig in insects of the genus *Sphinx*.

In order to carry out fully the comparison of the entochondrite of *Limulus* with that of *Scorpio*, it became necessary to make an investigation of the muscles attached to this organ in each case, and this has led on to a general investigation of the whole muscular system and its related supports in the two animals. The investigation of *Limulus* has been carried out by Mr. Benham, that of *Scorpio* by Miss Beck. No account of the muscular system of either animal has before been given, although imperfect descriptions of parts of the muscular system of *Limulus* are to be found both in the memoirs of Owen and of Alphonse Milne-Edwards.

As might be expected, we find a considerable specialization of the muscular system in the two animals compared, resulting in a wide divergence as to certain muscles; but there remain, nevertheless, certain agreements which are of the most striking and important character.

¹ Since published, in January 1884.

² I have since found a rudimentary structure of the kind in *Apus* (Quart. Journ. Micr. Sci., January 1884).

It will be sufficient to point out here, by way of introduction, that necessarily in *Scorpio* the muscles to the appendages of the mesosoma are almost entirely suppressed (those of the last four pairs of appendages, which have become lung-books, entirely), whilst, on the other hand, the same muscles are large and functionally important in *Limulus*. Again, in *Scorpio* the free articulation of the segments of the mesosoma and of the metasoma is retained, and accordingly the musculature connected with that articulation is developed. In *Limulus*, on the other hand, the segments of the mesosoma are ankylosed, and there are consequently no intersegmental muscles. One great joint, however, that between prosoma and mesosoma, is retained by *Limulus*; and accordingly, in connexion with that one joint, we find an enormous and specialized muscular development, differing from anything in *Scorpio*.

The most remarkable agreements to which the reader's attention is directed beforehand are in respect of (1) a large number of the muscles attached to the prosomatic entochondrite; (2) certain of the muscles attached to the pectines of *Scorpio* and the first gill-bearing appendage of *Limulus* and to the related small entochondrites in both cases; (3) the muscles arising from the pericardium and inserted into the investment of the great venous sac, which in the one case lies at the base of a gill-book and in the other case forms the investment of the in-sunken lung-book. This is a most important agreement, since in each case the muscle must have a very definite and peculiar action in determining the flow of blood from the respiratory sinus to the heart. These muscles were described as "brides transparentes" by A. Milne-Edwards, in his account of the vascular system of *Limulus*. By Newport they were seen in the Scorpion, and figured in his drawing, fig. 27, pl. xiv. of the 'Philosophical Transactions' for 1843; but they are not described or referred to by him in any way, and their significance has never yet been pointed out.

Lastly, the agreement in the origin and insertion of the great dorso-ventral vertical muscles of the mesosoma is a prominent one. In the fourth Chapter of the present memoir a further discussion of the agreements and differences of the muscular system in *Scorpio* and *Limulus* will be found.

PART II. *Description of the Muscular and Endoskeletal Systems of Limulus.*

By W. B. S. BENHAM, B.Sc.

HARD PARTS.

*Some of the Hard Parts in Limulus to which Muscles are attached.*I. *The Tergites.*a. *External View.*

1. *The Prosomatic Carapace* has a horseshoe-shape, rounded and convex in front and at the sides, which latter are produced beyond the central portion, ending in a point behind. (For a general description and figures of the segments fused to form the anterior and posterior carapaces of *Limulus*, see Lankester, "*Limulus* an Arachnid," Quart. Journ. Micr. Sci. 1882.)

The carapace is bounded behind by an almost straight line, reaching about halfway on each side of the middle line. This straight portion bends sharply downwards, so that the posterior border is nearly vertical, but of little depth. In the middle of this portion is an arch, and on each side of this is a slight depression running forwards along the carapace to about half its length: this depression produces a ridge on the inner surface, at the posterior end of which an invagination of the chitin has taken place, forming a pair of entapophyses (Pls. LXXIII., LXXV., and LXXVI., *Ent*¹), indicated externally by a shallow pit, on each side of this hinder arch, and situated in the vertical border.

Outside these two parallel depressions, about two thirds from the middle line to the edge of the carapace, is a slight longitudinal ridge; on this ridge are situated the lateral eyes. It is outside this ridge that the carapace commences its downward course.

2. *Meso-metasomatic Carapace.*—The hinder border of the prosomatic carapace is joined to the front edge of the abdominal (meso-metasomatic) carapace by a leathery membrane extending right along the straight border; on this border is an arch corresponding to that in the prosomatic carapace. This front border is bent slightly downwards, and at the end of the straight piece bends backwards and outwards, parallel with the recurved portion of the sides of the prosomatic carapace. About halfway along this oblique border is a ridge, ending in a point directed outwards. At the edge the meso-metasomatic carapace is produced into six sharp recurved points, between each consecutive pair of which is a rounded excavation in which is articulated a movable spine: there are thus six pairs of movable spines to this

carapace. Behind the last of these the edge is continued into a point similar to that of the recurved hinder portion of the prosomatic carapace. Behind the arch in the anterior border is a median arched portion of the carapace, transversely marked by six very slight depressions; between each of these, at the side of the arched part, is a pair of pits, the point of invagination of six pairs of "entapophyses" (*Owen*). Outside this line the carapace slopes downwards to the edge. Behind the last pit of invagination is a smoother part, which extends a short way backwards, and is continued outwards to form the posterior portion of the edge, which ends in a point. The hinder edge of the abdominal carapace is scooped out; in the bay thus formed a postanal spine is articulated by means of a strong membrane.

3. *The Postanal Spine* itself consists of a long tapering piece, triangular in section, with the apex of the triangle upwards. It is the hinder portion of the typical "telsonic" segment, and is the exact equivalent of the Scorpion's "sting." At its articulation with the body it has a dorsal process, which curves slightly forwards, and has the strong articulating membrane attached to it. The basal piece spreads out, and is likewise continued slightly forwards, and has also the strong membrane attached (Pl. LXXIII. *sp.*).

b. *Internal Aspect.* (Plate LXXVI. fig. 1.)

1. *The Prosomatic Carapace* is thus concave when seen from below and within, running downwards in front and at the sides to join the sternite. Behind, from the vertical border, rise the entapophyses; these are strong processes, triangular in transverse section at their base, but flattened and broadened at their free ends; they are directed forwards, downwards, and slightly inwards (*ent*¹). To these structures various muscles are attached.

From each of these entapophyses there runs forward a ridge (seen as a depression from without) with slight minor ridges branching at the sides; outside this are attached the main coxotergal muscles, each attachment being roughly separated by a slight ridge from its neighbours (25, 26, 28, &c.); within the ridge are attached other muscles from the coxæ, and from the plastron and from the abdominal appendages (18, 51, 52, &c.). Lying along the posterior edge of the carapace is a curious network of chitin (Pl. LXXVI. N); this is continued forwards along the line of the lateral eyes.

2. The inner surface of the *Abdominal (Meso-metasomatic) Carapace* is far less extensive. It is in front continuous with the hinder portion of the prosomatic carapace, and thence backwards this surface narrows till behind it has only the width of the postanal spine.

At the sides the floor of the mesosoma rises upwards, meeting it above the mesosomatic appendages just beyond the line of the entapophyses; thence the two, fused together, continue outwards as a thin plate for a short way. This then rapidly thickens

a great deal, and becomes triangular in cross section, with its base horizontal; this is pierced by a lateral canal, in which runs an artery supplying the movable spines (Pl. LXXVI. figs. 10, 11). This canal is open behind into the metasoma, and in front curves along the oblique anterior edge of the abdominal carapace and opens into the prosomatic cavity.

On each side of the median arch mentioned above, are situated six entapophyses (Pl. LXXVI. *Ent*² to *Ent*⁷), smaller than the pair in the prosomatic carapace, but with the same direction; each is smaller than its predecessor, the last being very short. Five of these belong to the mesosoma, the first of the six fused segments of which has no entapophysis: the last belongs to the metasoma. They all vary a good deal in shape, though in general they are flattened laterally. Several muscles are attached to each of these, as will be seen later on.

Along the anterior edge is a similar chitinous network to that found on the prosomatic carapace. This is continuous along the line of the entapophyses, leaving spaces for attachment for muscles, and is found elsewhere.

II. *The Sternites* (seen from within). (Plate LXXII.)

1. *Prosomatic Region*.—Outside the attachments of the limbs, whose basal joints form the sides of the prosomatic region, the ventral hard chitinous portion of this region curves outwards and downwards to join the dorsal portion (lateral convexity): thus the floor of the prosoma, at the sides, is convex from within, and there is only a very shallow space between tergite and sternite.

Anteriorly, in the median portion, there is a triangular flat portion, the subfrontal area (*Sfa*), which forms the floor of a much deeper space between tergite and sternite, in which is lodged the muscular stomach. The sides of this triangular space curve upwards and outwards, forming a continuation with the general convex sternal portion outside the coxal attachments. The apex, which is median and posterior, has an almost vertical wall, which rises for a short distance and is then continued as a chitinous membrane backwards.

The median portion of the floor of the prosoma, the real sternal region of this division of the body, above which are lodged the various organs, is principally membranous, with certain chitinous sclerites here and there.

The mouth is situated in almost the centre of this part, between the bases of the third pair of prosomatic limbs. The œsophagus (*œ*) is of chitinous membrane, and has harder ridges along it, which radiate along the floor of the prosoma towards the coxæ of the limbs.

In front of the mouth, and between the coxæ of the first pair of prosomatic appendages, is an ovate piece of hard chitin, the sclerite of the "camerostoma" of Latreille, which forms a sort of upper lip (*Cam*).

In front of this, in the median line, is another sclerite, the subfrontal sclerite (*Sf*).

Behind the mouth is a large somewhat pear-shaped sclerite, with its broad end directed backwards: this is the pro-meso-sternite (marked *p.m.st* in Pl. LXXVI.).

Behind this come the two apertures leading into the chilaria (*mtst*), identified by Prof. Lankester as the metasternite. Mr. Packard has shown by their development that they do not belong to the series of appendages, and it is obvious enough that they represent the pentagonal or triangular sternal sclerite of the Scorpions.

Slightly behind these, and high up the sides of the membrane, behind the last entocoxite, where the membrane rises upwards to join the outward-sloping sternite of chitin, is a sclerite on each side, the lateral sclerite (Pl. LXXVI. *lat.scl*).

The sides of the prosomatic region are formed simply by the basal joints of the appendages. These basal joints are elongated dorso-ventrally, forming an entocoxite; and, while the top of this portion, in each case, is attached to the "lateral convexity" (convex chitinous sternal portion of the prosoma), the lower part and the sides are simply held in place by chitinous membrane, which extends all along the ventral median region and up between the basal portion of the limbs to reach the lateral convexity (chitinous portion of the prosomatic floor). This holds for the hinder five pairs of prosomatic appendages; but the first pair is not articulated to any hard part, but simply lies in the membrane. Instead of having an anterior and posterior border to the entocoxite (*vide* below) there is only one bar to each: and anterior to this, in a line with it, are two sclerites on each side (near the word *Cam* in Pl. LXXII.).

Each of the last five pairs of thoracic limbs is attached to the lateral convexity (sternal chitinous portion) of the thorax by means of a knob, at the top of the entocoxite; this articulates with a little hollow in a thickened portion of chitin, whence diverge two rods of harder chitin. This structure, the knob and two rods of hard chitin, continuous with and part of the lateral convexity (chitinous sternite), may be called the coxal pivot or hyper-coxite (see fig. 7, Pl. LXXVI.).

The Floor of the Abdomen (meso- and metasoma).—This is continuous with the median floor of the prosoma, and, like it, is membranous. It narrows posteriorly, and is interrupted by six transverse hollows (VII to XII), leading into the six mesosomatic appendages, viz. the genital operculum and five gill-plates. From the hinder edge of each of these hollows there rises on each side, near the middle line, a hollow tendon (*ts*¹ to *ts*⁶), continuous posteriorly with the stigmata on the base of the abdominal appendages, and at their anterior ends having each a muscle inserted. These tendons and their stigmata will be found described and figured in Prof. Lankester's Memoir "*Limulus* an Arachnid."

Between each pair of these "tendinous stigmata" is situated in the middle line, on the posterior border of the transverse hollows in the floor, a small rectangular cartilaginous "entochondrite," to which muscles are attached (*s*¹ to *s*⁶).

Thus there are six of these abdominal entochondrites, and six pairs of tendinous stigmata.

The sides of the mesosoma rise up, and are continuous with a chitinous portion, which continues outwards, and becomes fused with the tergite; the two thus fused are continued laterally for a short distance, then separate again and thicken out, containing a canal, carrying an artery &c. to the movable abdominal spines. The floor of this is horizontal.

The membranous floor of the mesosoma is continuous behind with the chitinous floor of the metasoma; this is scooped out on its anterior border, in the middle line; in the hollow thus formed is situated the last entochondrite, and to the sides of this hollow are attached the last pair of tendinous stigmata (see Pl. LXXII.). The metasomatic floor itself bends sharply downwards, widens posteriorly, and curves upwards at the sides to join the tergite; thus it is concave from within. This metasomatic cavity is continuous with the lateral canal above mentioned.

The hinder border, which is almost flat, is scooped out; and in this bay is situated the anus, surrounded by a membrane similar to that round the mouth (R). Behind this is the postanal spine (*sp*).

Thus, if the abdominal region be looked at from below, supposing the appendages to be removed, the sides curve upwards towards the observer (downwards, of course, in its natural position), and outside this is the flattened floor of the lateral canal.

On the concave sides are five transverse lines (see woodcut, fig. 3, in Lankester's "*Limulus* an Arachnid"), corresponding with those slight depressions seen on the abdominal tergite, starting from between each pair of entapophyses. From the last line rises upwards (downwards in natural position) the metasomatic sternite. This line starts between the sixth and seventh entapophyses, so that the latter lies in the metasoma, and, as will be seen by the muscles attached to it, must be considered as belonging to this portion. In the same way the muscles attached to the first pair of entapophyses, which are invaginated from the posterior vertical border of the prosomatic carapace, seem to show that these belong really to the mesosoma.

The *microscopical structure* of the carapace shows it to consist of three layers of chitin of various thicknesses, the outermost being very thin and remaining yellow, while the second remains almost colourless, and the innermost deeply stained under the action of borax-carminé. The middle layer shows fine wavy lines parallel to the surface, as well as finer transverse striations. The inner layer is more coarsely striated, mainly transversely, but sometimes obliquely, to the surface.

These layers are traversed by fine tubes, which on reaching the outer layer contract suddenly into an exceedingly fine capillary; these contain connective tissues, and to some are attached hairs, around whose bases the external layer is depressed into a small pit.

Below the outermost layer of chitin are the flattened epidermic cells which produced the cuticle; these are surrounded by pigment, or contain pigment.

In the case of the network on the inner surface of the carapace, the layers of chitin, except the outermost, are continued, surrounding spaces filled with connective tissues. The tubes piercing the layers are more or less filled with connective tissue-cells.

III. Appendages.

1. *Prosomatic Appendages*.—Of the six pairs of prosomatic appendages, the five hinder pairs are more or less alike (the walking-legs), the last being used for digging as well as walking. The first pair is much smaller and has fewer joints.

The proximal joint (coxa) of a walking-leg is a short piece, widening out from its distal end dorso-ventrally till it becomes very wide at its attachment to the body.

Attached to the coxa of the third, fourth, and fifth pairs is a small movable piece, described by Lankester as the epicoxite, and directed towards the middle line.

The coxa itself, where it projects below the floor of the thorax, is strongly toothed; this portion is the sterno-coxal process, and is used for manducatory purposes.

The sterno-coxal process of the sixth proximal appendage is not toothed but is slightly roughened.

When the base of a walking-leg is looked at from within the body (see Pl. LXXXII. and Pl. LXXVI. fig. 7) there are seen, rising almost vertically from the sterno-coxal process, two narrow chitinous bars, at first diverging from one another, so as to form an anterior and posterior border to this portion; to these borders various muscles are attached. After running nearly parallel for a short distance, and inclined outwards, they converge and meet in a slightly thicker piece; from the posterior end of this a short thick bar rises upwards and backwards, whilst from its anterior end another piece goes upwards and forwards to a *knob*, which articulates with the "coxal pivot" on the "sternal convexity." From this a rod goes backwards to meet the anterior short bar; the part where they meet is a rounded knob, into which the principal coxo-tergal muscle is inserted. Other smaller bars go from the anterior border to this articular "knob."

Each of these sets of chitinous bars may be termed an "*entocoxite*."

The first thoracic appendage differs from this in that there is but a single chitinous rod passing upwards, forwards, and outwards from the coxa along the membranous sternal region in front of the camerostome, at the side of which the coxa is situated.

This single rod probably represents the posterior border of the other entocoxites, judging from the insertion of its muscles. The entocoxite is not fixed to any hard structure at its upper and anterior end, and in a line with it are two small sclerites.

2. *Mesosomatic Appendages*. a. *Gill-plates*.—Of these there are five pairs, each pair being united across the median plane.

The appendage consists of a bag, flattened antero-posteriorly, open to the mesosomatic

cavity above; the sides of this bag may be termed the anterior and posterior lamellæ. Across the middle line, for a short distance on each side, these two lamellæ are free from one another and membranous, and are produced in the middle line ventrally as a membranous tongue-like appendix called the sternal lobe (Pl. LXXIII. fig. 4, *ml*), containing a space continuous with that between the lamellæ.

A single branchiferous appendage, considered apart from its fellow to which it is joined across the middle line, consists of a broad, flat, chitinous basal piece, which carries the gill-book on its posterior face. From this basal joint there springs a broad chitinous exite on the outer side, and on the inner side the limb continues in three joints, the last of which hangs pretty freely downwards at the side of the membranous tongue already spoken of as the sternal lobe (see Pl. LXXIII. fig. 4). The gill-book is placed on the basal joint outside the posterior lamella, and consists of about 150 double leaves, the double leaf being a flattened bag of two plates opening into the space between the anterior and posterior lamellæ of the appendage. Of these the smallest is placed anteriorly, and the largest posteriorly, each one overlying the succeeding lower one.

The anterior lamella of the branchiferous limb is strengthened by two chitinous bars, one going obliquely outwards, the other passing downwards along a flat chitinous plate, which is situated just outside the sternal lobe. To these chitinous pieces some of the muscles of the appendage are attached. On the posterior lamellæ are also one or two small sclerites (see Pl. LXXIII. fig. 4).

Close to the base of the sternal lobe, on each side, and close to the middle line, is situated a stigma (*stg*); this leads into a hollow tendon, which passes upwards and forwards for about $\frac{3}{4}$ inch, and in its anterior end is inserted a muscle. The six muscles from these tendinous stigmata on each side form the two large branchio-thoracic muscles, which raise the floor of the abdomen by their contraction.

The chitinous supports of the anterior lamellæ have a similar structure to that of the other chitinous parts, but bear some very curious large hairs inserted in cups situated in the outer layer of chitin. These compressed hairs are of two sorts, large and small; the large ones have a number of flat processes standing out from the sides, into each of which apparently a canal runs. The smaller kind of hair is narrower, and bears more needle-shaped processes on it.

b. *The Genital Operculum*.—This is formed of a right and a left portion, which have fused more completely across the middle line than have the lamelliferous appendages. It consists of an anterior and posterior lamella, which are separate and chitinous right across, there being no membranous "sternal lobe" nor tongue-like appendix (Pl. LXXIV. figs. 4, 5).

The posterior lamella bears no gill-book; but about one third of the way from the base of the appendage, and near the middle line, are a pair of small chitinous papillæ;

these are pierced by the genital apertures; each leads into a duct, which passes upwards and slightly outwards, lying parallel to the "posterior lamellar" muscle, coming nearly up to the thoracic carapace, alongside the sixth coxotergal muscle; here it breaks up into branches.

There are a pair of tendinous stigmata, and in all other respects the genital operculum is similar to the succeeding appendages.

IV. *Entochondrites.*

1. *Prosomatic or Plastron*.—This internal skeletal structure (Pl. LXXXVI. figs. 3, 4, 5, 6) is a flat, roughly rectangular, cartilaginous body, with its longer axis directed antero-posteriorly. It lies in the centre of the prosoma, above the mouth and nerve-collar, between the entocoxites, to which a large number of muscles pass from it. Dorsal to it lies first the alimentary canal, and then the anterior aortic trunk. Muscles pass from it to other parts.

It is convenient for subsequent use in the terminology of the muscles to apply the name "plastron" to the prosomatic entochondrite.

The general flat surface may be called the "*body*" of the entochondrite or plastron; its anterior border is concave anteriorly, and each side is produced forwards as a short stout process, to which various muscles are attached: these may be called the "*anterior cornua*" (*A.c.en.*).

The front edge is produced laterally into a long slender bar of cartilage, which, rising outwards and upwards, passes between the third and fourth entocoxites; to the distal end of this process is inserted a short muscle, attaching it to the carapace outside the coxotergal muscles.

Behind this, and springing close to it, is a second long process; this passes outwards between the fourth and fifth entocoxites, and like the front one is attached to the carapace by a muscle beyond the coxotergals. These may be called the "*lateral cornua*" (*l.c.en.*).

The hinder part of the side of the "*body*" passes outwards, and with the produced posterior edge of the entochondrite forms a "*latero-posterior process*" on each side (*l.p.c.en.*).

Posteriorly, in the middle line, is a "*posterior process*," which rises very slightly above the "*body*" (*p.c.en.*).

From the dorsal face of this entochondrite, just behind the base of this hinder lateral cornu, is a short stout "*dorsal process*" (*d.c.en.*) on each side, which rises backwards, upwards, and slightly outwards.

To all these processes are attached muscles, some from the thoracic appendages, others going to the carapace &c.

The microscopic structure of this organ has been described by Prof. Lankester since

this Memoir was in type; the reader is referred to his paper in Quart. Journ. Micr. Sci., Jan. 1884.

2. *Mesosomatic Entochondrites*.—There are six of these, lying on the floor of the mesosoma on the hinder border of the bases of the appendages (see Pl. LXXII. for their position). The nerve-cord is *dorsal* to these entochondrites, and not below them as it is in the case of the plastron. They are more or less rectangular in shape, with their long axis transversely directed (Pl. LXXVI. fig. 8). The anterior and posterior corners are slightly produced, giving attachment to muscles. On the median ventral surface is a ridge.

These have the same microscopic structure as the plastron.

V. *The Entapophyses*.

There are seven pairs of these, one on the thoracic carapace on its hinder vertical border, the rest in a line with these on the abdominal carapace. Each consists of an invagination of the chitin to form a strong process, directed forwards, downwards, and slightly inwards; they are flattened from side to side. Several muscles are attached to each entapophysis; thus, *e. g.*, on the inner face, anteriorly, are attached the bundles of the oblique muscle (1, 2, 3); posteriorly, in the case of the last three, the ventral pygo-tergal (9); to the ventral edge, the posterior lamellar muscle (23) from the abdominal appendage of the same segment; on the outer surface, ventrally, the posterior lamellar muscle (22) from the succeeding abdominal appendage; posteriorly, the dorsal pygal muscle (6). To different entapophyses are attached different muscles.

To the outer edge of each entapophysis is attached a half-ring of hyaline cartilage (capsuligenous tissue of Lankester) by the intervention of some fibro-cartilage (fibro-massive tissue of Lankester); by means of this ring some of the muscles from the abdominal appendages are attached.

The fibro-massive tissue is continuous from each entapophysis to the next one, and forms a definite band-like structure on each side of the mesosoma, to which I give the name of "entapophysial ligament" (Pl. LXXIII. *ee*): it ends in the postabdominal sternite.

Microscopic Structure.—The entapophyses are similar to the carapace; the outermost layer of chitin in the latter now, of course, lines the cavity which exists within the entapophysis: the layers are a good deal contorted, and are pierced by tubes in the same way as is the carapace. Some of these carry hairs, which project within the cavity.

Below the chitin are seen the epidermic cells which produce the chitin. These are a good deal obscured by pigment.

VI. *Tendinous Stigmata.*

These are invaginations of the cuticle near the base of the abdominal appendages, one on each side of the middle line on the posterior face of each appendage: the hollow invagination is as much as one inch in depth (Pl. LXXXIV. figs. 4, 5, *st*).

The stigma is at first composed of two or three layers of epidermal chitin; then, as we pass inwards, we find it invested by fibrous connective tissue forming a tendon, to which the branchio-thoracic muscle is attached.

MUSCLES.

I. *The Longitudinal Muscles.*

The Prosoma and the Mesosoma.—These cannot be separated, as the principal muscles rise in the prosoma, but mainly lie in the mesosoma.

No. 1. *The Dorsal Entapophysio-plastral.*—This rises on the dorsal face of the posterior process of the plastron or prosomatic entochondrite, beneath 54, and passes over the base or attachment of the dorsal plastro-tergal muscle (55), directly backwards into the mesosoma, below the intestine, just on each side of the median plane (Pl. LXXIII. figs. 1, 2, and Pl. LXXVI. fig. 4). On reaching the mesosoma it gives off a bundle (83) to the third entapophysis, to which structure it is attached on the anterior edge. The main muscle then passes on, giving off a bundle successively, to each of the following entapophyses (84, 85, 86), nos. 4, 5, 6, the main bundle (87) running on to the last entapophysis—the metasomatic. In its course it includes the vertical mesosomatic muscles (12) between the main bundle and each branch to the entapophyses.

No. 2. *The Ventral Entapophysio-plastral.*—This rises from the dorsal face of the plastron, nearly covering this structure, passing beneath no. 54; like the preceding, just below which it passes, it runs into the mesosoma, breaking up into bundles, which go to the entapophyses 3, 4, 5, and 6. It likewise ends in the metasomatic (seventh) entapophysis. Just outside its branches rise the veno-pericardiac muscles (68).

The branch to the third entapophysis is lettered 103 in the Plates.

The branches to the fourth, fifth, and sixth entapophyses are lettered 104, 105, 106 respectively.

The terminal slip (107) is inserted into seventh entapophysis.

No. 3. *The Ventral Longitudinal.*—This is a much smaller muscle than either of the preceding, lying on the abdominal floor. It is shown in Pl. LXXV. fig. 3. It rises from the dorsal face of the plastron underneath the origin of no. 2. On reaching the mesosoma it gives off a bundle (no. 69) to the second mesosomatic entochondrite. It

gives off similar bundles (70, 71) to the next two entochondrites, as well as bundles (74, 75, 76, 77) to the fourth, fifth, sixth, and seventh entapophyses.

It is continued backwards on the floor of the abdomen, after giving off its last slip, and is inserted into the metasomatic sternite.

No. 4. *The Inter-entapophysial Muscles*.—Of these there are four (best seen in Pl. LXXV. fig. 2):—

4 *a*. A small one running from the hinder edge of the first entapophysis to the anterior inner face of the second.

4 *b*. A larger one from the first to the third.

4 *c*. From the first to the fourth.

4 *d*. From the first to the fifth.

These lie successively lower, no. 4 *a* being uppermost.

No. 78. *The Arthrotergal Muscle* (Pl. LXXV. fig. 2).—This large muscle passes from the tergum of the prosoma to the tergum of the mesosoma, across the joint; it assists in flexing the prosoma on the mesosoma.

No. 5. *Intersternal or Longitudinal Muscle*.—Rising from the dorsal face of the plastron close to the posterior process of this structure, it passes from segment to segment of the mesosoma, being attached in each case to the mesosomatic entochondrites, and ending in the metasomatic sternite, being fixed near its anterior edge (Pl. LXXV. fig. 3).

The Longitudinal Muscles of the Metasoma.

No. 6. *Internal Pygo-tergal Muscle*.—Arising close to the median plane, from the membrane (*mb*) attached to the dorsal process of the post-anal spine, it passes almost directly forwards, being attached partly to the carapace (6); then passing forwards it is attached successively to the inner faces of the metasomatic, the sixth, and the fifth entapophyses, by its branches 91, 92, and 93 respectively.

No. 7. *Middle Pygo-sternal*.—Arising also from the membrane above mentioned more laterally than no. 6, it passes laterally forwards, to be inserted into the carapace, splitting into branches 94, 95, which are inserted into that part of the metasomatic sternite (*p, ab, st*) which rises sharply upwards to join the carapace.

No. 8. *The External Pygo-tergal* has the same arrangement as no. 7, but is placed more laterally, and slightly ventrally; its slips to the metasomatic sternite are lettered 96, 97.

No. 9. *The Ventral Entapophysio-pygal*.—This muscle arises below no. 6 in the membrane of the main part of the spine, runs forwards, and is inserted into the seventh, sixth, and fifth entapophyses on their outer faces by branches 90, 88, and 89 respectively.

No. 10. *The Inner Sterno-pygal* arises in membrane at the basal portion of the spine,

and runs slightly outwards and forwards to the uprising portion of the post-abdominal sternite, to which it is attached. It is more laterally placed than no. 9, and below no. 7.

No. 11. *The Outer Sterno-pygæal* arises from the basal membrane of the spine more laterally than no. 10. Passing below no. 8 it is attached to the floor of the metasoma.

No. 61. A few muscular fibres, rising in the floor of the fourth mesosomatic segment, run to the fifth and thence to the sixth segment, and end in the metasomatic sternite, a good deal mixed with nos. 3 and 5.

II. *Dorso-ventral Muscles.* (Plate LXXV.)

No. 12. *The Vertical Mesosomatic Muscles.*—Of these there are six on each side. Each is inserted into one of the six mesosomatic (or abdominal) entochondrites on its outer edge, and rising slightly obliquely across the bundles of no. 1, between the branches of which it passes, is attached to the tergum anteriorly to the base of each of the entapophyses, its general course being vertical. [It is especially noteworthy that the first pair of this series passes from the entochondrite of the genital operculum to the *prosomatic* tergum, being attached just in front of the great entapophysis on each side.—E. R. L.]

No. 13. *The Oblique Entapophysio-sternals.*—A muscle from the second mesosomatic entochondrite passes backwards, upwards, and outwards above no. 3, and below the branches of no. 2, to its attachment to the deep (free) end of the fourth entapophysis.

No. 14. A muscle, with a similar course, from the third mesosomatic entochondrite to the fifth entapophysis.

No. 15. A similar muscle from the fourth mesosomatic entochondrite to the sixth entapophysis.

No. 16. A similar muscle from the fourth mesosomatic entochondrite to the metasomatic (seventh) entapophysis.

No. 17. A similar muscle from the fifth abdominal entochondrite to the metasomatic (seventh) entapophysis.

No. 18. *The Branchio-thoracic Muscles.*—A series of muscles pass from the hollow tendons which open at the stigmata of the mesosomatic appendages. There are six pairs of these. Each tendon has attached to it a thickening bundle of muscle which in its passage upwards and forwards passes outside no. 12 muscle to the inside of the entapophyses, beneath the dorsal lateral plastro-tergal muscle (52) to its attachment to the carapace in the prosoma, alongside that of the coxo-tergal muscles, but nearer the median plane.

No. 19. From the bundle attached to the last stigma (see Pl. LXXV. fig. 1), before it has joined those arising from the anterior stigmata, there rises a muscle which passes more directly upwards than the mass of the branchio-thoracic, and is attached to the inner posterior face of the second entapophysis.

No. 20. *The External Branchial Muscles*.—Inserted in the anterior lamella of the genital operculum is a large muscle which passes at first upwards (Pl. LXXV. fig. 1); then, when it leaves the appendage, it passes outwards, backwards, and upwards, outside the other muscles of the metasoma to its attachment on the anterior border of the mesosomatic carapace, outside the line formed by the bases of the entapophyses (Pl. LXXIV. fig. 1, and Pl. LXXVI. fig. 1).

There is a similar pair of muscles in each of the other five mesosomatic appendages. [These are attached at their tergal origins near the corresponding entapophysis (Pl. LXXV. fig. 7). There is no entapophysis to the tergum of the genital segment, as is rendered obvious by the position of this muscular attachment, unless we may consider the great prosomatic entapophyses as originally belonging to that segment, but transferred and ankylosed to the prosoma, just in the same way as the body of the atlas vertebra of mammals is transferred to the axis.—E. R. L.]

No. 21. *Anterior Entapophysio-branchial Muscles*.—Nearer the middle line than no. 20 is a smaller muscle inserted in the anterior lamella of the genital operculum, and passing nearly directly upwards, and slightly outwards, outside all the other muscles of the mesosoma but no. 20, to its attachment to the great prosomatic entapophysis (see Pl. LXXIV. fig. 1).

A similar muscle occurs in each of the five succeeding mesosomatic appendages, each attached to the entapophysis of its own segment.

No. 22. *Posterior Entapophysio-branchial Muscles*.—From the posterior lamella of the genital operculum there goes a muscle upwards and forwards, beneath the muscle 1, to its attachment on the prosomatic carapace, alongside the sixth coxo-tergal muscle, nearer the median plane.

In each of the five succeeding mesosomatic appendages is a similar muscle, but each is attached to the entapophysis of the preceding segment; thus this muscle from the second mesosomatic appendage is attached to the great prosomatic or first entapophysis, that from the third to the second entapophysis, and so on.

No. 23. *Pre-entapophysio-branchial Muscles*.—In the second and following mesosomatic appendages is a second muscle, attached in each case to the entapophysis of the preceding segment, but inserted into the *anterior* instead of the *posterior* lamella of the appendage.

No. 65. *Chilarial Muscles*.—A small muscle passes from the posterior process of the prosomatic entochondrite into the chilaria.

III. *Muscles of the Appendages.*

a. *Prosomatic Appendages*. No. 24. *The Tergo-coxal Muscles of the first Pair*.—From the coxa of the first prosomatic appendage a small muscle rises nearly vertically, passing just across the inner border of the anterior cornu of the prosomatic entochondrite, and between the muscles of this process to the carapace, to which it is attached

on the level of the third coxo-tergal (the second large muscle seen on opening the animal), but nearer the median line.

No. 25. *The Tergo-coxals of the second, third, fourth, fifth, and sixth Pairs.*—A large muscle, short, but thickening rapidly, is attached to the rounded knob at the top of the ring formed by the two borders of the entocoxite of each of the five following prosomatic limbs (25 *a*, 25 *b*, 25 *c*, 25 *d*, 25 *e*). They arise from the carapace in order one behind the other (Pl. LXXVI. fig. 1 and fig. 7, also Pl. LXXIII.).

No. 26. *Antero-superior Tergo-coxal Muscles.*

No. 27. *Antero-inferior Tergo-coxal Muscles.*

No. 28. *Postero-superior Tergo-coxal Muscles.*

No. 29. *Postero-inferior Tergo-coxal Muscles.*

These four sets of muscles are found in connexion with each of the five pairs of prosomatic appendages succeeding the first. They are inserted into different parts of the entocoxite of each limb, as shown in Pl. LXXVI. fig. 7, and arise from areae on the carapace surrounding the origin of the muscles 25 *a*, 25 *b*, 25 *c*, 25 *d*, and 25 *e*.

No. 30. *Anterior Plastro-coxal Muscle.*—A muscle attached to the inner ventral face of the anterior cornu of the prosomatic entochondrite, and passing forwards is inserted into the anterior face of the rod-like entocoxite of the first prosomatic appendage.

No. 31. *Posterior Plastro-coxal Muscle.*—A muscle arising behind no. 30, from the entochondrite, also goes to the entocoxite of the first appendage, but is inserted below no. 30.

No. 32. *Superior Plastro-coxal Muscle.*—A muscle arising from the outer face of the anterior cornu of the prosomatic entochondrite, passes slightly forwards, enters the space bounded by the two borders of the entocoxite of the second limb; it here breaks up into two—*m* going to the inner face of the anterior, *n* to the inner face of the posterior border. Here they each spread out, passing upwards; they do not go far into the coxa. For this and nos. 33, 34, see Pl. LXXVI. fig. 7.

No. 33. *Mid Plastro-coxal Muscle.*—This muscle rises below no. 32 from the entochondrite, and passes slightly forwards; it is inserted into the posterior border of the entocoxite of the second limb.

No. 34. *Inferior Plastro-coxal Muscle.*—Rises behind and below no. 33 from the under-surface of the body of the entochondrite, and passing forwards, below no. 33, is inserted into the anterior border of the entocoxite of the second prosomatic limb.

No. 35. { *o*, its anterior; *p*, its posterior branch.

No. 36. { These muscles go to the third prosomatic appendage, and have a similar

No. 37. { course to nos. 32, 33, 34.

No. 38. This muscle is similar to 32 and 35, rises behind them, and goes to the fourth appendage: *q*, its anterior; *r*, its posterior branch.

No. 39. This muscle passes in a more backward direction from its origin in the edge of the entochondrite to the fourth entocoxite (corresponds to 33).

No. 40. This muscle passes beneath 39, and goes to the fourth entocoxite (corresponds to 34).

No. 41. This muscle is similar to 32, 35, and 38, and goes to the fifth prosomatic appendage: *s*, its anterior; *t*, posterior branch.

No. 42. This muscle lies parallel to but behind 39, and passes backwards to the fifth appendage (corresponds to 33, 36, and 39).

No. 43. This muscle rises under and behind 40, passes beneath 42, and goes to fifth limb. It corresponds to 34, 37, and 40.

No. 44. This muscle is similar to 32, 35, 38, and 41, and goes to sixth appendage: *y*, its anterior, *z*, its posterior branch. It rises from the postero-lateral process of the entochondrite.

No. 45. Rises behind 42, runs parallel to it, and goes to the sixth appendage, passing under 44.

No. 46. This is a much larger muscle than the corresponding ones 34, 37, 40, 43, rising from the middle line of the ventral surface of the body of the prosomatic entochondrite, beneath and behind the previous muscles of the limbs, and, passing rather backwards, goes to the sixth appendage.

No. 47. Is smaller than 46, rises behind it, and goes outwards to the entocoxite of the sixth appendage.

No. 60. Rises from the postero-lateral process of the plastron behind 44, and goes to the posterior border of the entocoxite.

b. *Mesosomatic Appendages*.—The muscles connected with these have nearly all been described under the heading "Dorso-ventral Muscles." These are:—

No. 20. *The external branchials*: six pairs.

No. 21. *The anterior entapophysio-branchials*: six pairs.

No. 22. *The posterior entapophysio-branchials*.

No. 23. *The pre-entapophysio-branchials*: five pairs.

No. 48. *The Internal Branchial Muscles*.—Rising from the ventral ridge of the first mesosomatic entochondrite a small muscle dips into the genital operculum, and is distributed partly to its anterior and partly to its posterior lamella (see Pl. LXXIV. figs. 4 & 5).

A similar muscle occurs in the five succeeding appendages (Pl. LXXIV. fig. 3).

No. 18. *The Branchio-thoracic Muscles* have been described above; they rise from the tendinous portion of the stigmata, which lie at the base of the posterior lamella of each of the six pairs of mesosomatic appendages, near the middle line.

Nos. 112, 113. These muscles appear to be branches from no. 20 to the lobes of appendages (see fig. 3, Pl. LXXIV.).

No. 114. *Muscle of the Inner Lobe*.—This muscle passes from the sclerite (*a*), in each half of each appendage, to the extremity of the internal lobe.

No. 115. Branch of 48, to sclerite (*p*) on anterior face.

IV. *Muscles connected with the Plastron or Prosomatic Entochondrite not described in the preceding Sections.*

No. 49. *The Tergo-proplastral Muscles (Anterior Plastro-tergals).*—This muscle (*r* and *l*) is inserted into the inner side of the anterior cornu of the plastron, and passes outwards, upwards, and forwards to its attachment to the carapace, slightly in front of and mediad of the muscle 25.

No. 50. A smaller muscle, inserted behind 49, passes slightly forwards and upwards, in front of 24, to its attachment to the prosomatic carapace.

No. 51. Similarly inserted, passing behind 24 to its attachment to the carapace, behind and mediad of the third coxotergal (25 *b*).

No. 52. *The Dorso-lateral Plastro-tergal.*—This (*r* and *l*) is inserted into the dorsal process of the entochondrite, passes backwards, upwards, and outwards across no. 18, and is attached to the carapace in the same line with this latter muscle.

No. 53. *The Dorso-lateral Entapophysio-plastral.*—This muscle (*r* and *l*) is inserted on the hinder edge, near the base, of the dorsal process of the plastron, and passes upwards and backwards, and only very slightly outwards, crossing the attachments of no. 2, to the first entapophysis, to the anterior inner edge of which it is attached.

No. 54. *The Anterior Entapophysio-mesoplastral Muscles.*—Each of these (*r* and *l*) rises along the middle line of the dorsal surface of the "body" of the plastron, and passing across the attachment of no. 2, outwards, and slightly backwards and upwards, is attached to the first entapophysis alongside 53.

No. 55. *The Posterior Entapophysio-mesoplastral Muscles.*—Each (*r* and *l*) rises from the base of the posterior process of the plastron, and passing outwards, across no. 2, goes to the first entapophysis, to which it is attached close to 54.

No. 56. *The Posterior Entapophysio-metaplastral Muscles.*—Each (*r* and *l*) rises below 55, from the side of the posterior process, and passing outwards and backwards crosses no. 2, and is attached to the second entapophysis.

No. 57. *The Lateral Tergo-proplastral Muscles.*—A short muscle (*r* and *l*) is inserted into the distal end of the anterior lateral cornu of the plastron, and is attached to the carapace between nos. 25 (*b* and *c*), but outside the line formed by these muscles.

No. 58. A similar muscle (*r* and *l*) is inserted into the posterior lateral cornu, and is attached behind 57, between 25, *c* and *d*.

No. 59. A small muscle is inserted a short way down the posterior lateral cornu, and is attached to the carapace close to 25 (*d*).

No. 72. *The Vertical Entapophysio-metaplastral Muscles.*—Each (*r* and *l*) rises below 56, from the edge of the posterior process of the plastron, and passes to the third entapophysis.

No. 67. *Plastro-buccal Muscle.*—From the under-surface of the entochondrite, a few muscular fibres go to the œsophagus close to the mouth.

The other muscles attached to the plastron which have been mentioned in previous sections are:—

- No. 1, from its posterior process;
- No. 2, from the dorsal face of the body;
- No. 3, from the dorsal face of the body;

and those from the under-surface, 30 to 47, which go to the prosomatic appendages.

V. *Muscles connected with the six Mesosomatic Entochondrites.*

- First:* Muscle No. 5 from the prosomatic entochondrite is inserted here.
No. 12 (first pair of vertical mesosomatic muscles) is inserted here and passes vertically to the carapace.
- Second:* No. 5 passes on from its connexion with the *first* mesosomatic entochondrite.
No. 12 (second pair of vertical mesosomatic muscles).
No. 13, the first pair of oblique entapophysio-sternal muscles, passes from this entochondrite to the fourth entapophysis.
No. 62. *The first pair of mesosomatic intersternal muscles* passing from this to the fourth entochondrite.
No. 63. A similar muscle passing from this to the fifth entochondrite.
No. 69. A slip from the ventral longitudinal muscle (no. 3) is also inserted here.
- Third:* No. 5 continues from the second entochondrite. Also a third pair of vertical mesosomatic muscles, no. 12, and a slip (70) from no. 3 are inserted here.
No. 14, the *second* pair of oblique entapophysio-sternal muscles, goes hence to the fifth entapophysis.
- Fourth:* No. 64, the *second* pair of mesosomatic intersternal muscles, arises here and passes to the fifth entochondrite.
No. 5 is continued.
No. 12 is present as the fourth pair of vertical mesosomatic muscles.
No. 71 is a slip attached here from the great ventral longitudinal muscle, similar to the slips 69 and 70.
No. 15, the third pair of oblique entapophysio-sternal muscles, is inserted here, arising from the sixth pair of entapophyses.
No. 16, a fourth pair of oblique entapophysio-sternal muscles, arising from the seventh pair of entapophyses, is also inserted into the fourth mesosomatic entochondrite, as shown in fig. 3, Pl. LXXV. In fig. 1, Pl. LXXIV., it is represented as inserted into the fifth entochondrite. The drawings have been somewhat complicated and difficult to letter accurately. Apparently the muscle no. 16 is omitted in fig. 1, Pl. LXXIV., and that to which the reference 16 is attached should properly be lettered 17.
No. 62 arising from the second mesosomatic entochondrite, and noted above, is inserted here.

Fifth: No. 5 is continued.

No. 12 is present as the fifth pair of vertical mesosomatic muscles.

No. 17, a fifth pair of oblique entapophysio-sternal muscles, arising (like No. 16) from the seventh pair of entapophyses, is inserted into this fifth mesosomatic entochondrite.

No. 63 arising from the second mesosomatic entochondrite is inserted here.

No. 64 arising from the third mesosomatic entochondrite is inserted here.

Sixth: No. 5 is continued from the preceding entochondrite to this one, and passes on from this to its final insertion in the solid metasomatic sternite (epidermal chitin forming the floor of the hind part of the meso-metasomatic carapace).

No. 12 is present as the sixth and last pair of vertical mesosomatic muscles.

VI. *Pharyngeal.*

No. 66. *The Sterno-pharyngeal Muscles.*—From the ventral surface of the anterior curvature of the alimentary canal a number of muscular bands pass, though not in regular distinct bands, to the subfrontal area of the chitinous prosomatic carapace.

No. 67. *The Plastro-buccal Muscle.*—A few muscular fibres go from the œsophagus to the ventral surface of the entochondrite.

VII. *Pericardiac.*

No. 68. *The Veno-pericardiac Muscles.*—On the floor of the mesosoma (as in the Scorpion), on each side, near the middle line, is a blood-sinus, the “venous collecting-sinus” as M. Milne-Edwards calls it; here the blood collects from the body, on its way to be aerated in the leaves of the gill-books. From the floor of the sinus a vessel goes into each of the abdominal appendages; from the space between the anterior and posterior lamellæ of these it reaches the gill-books.

From the roof of this collecting-sinus in each abdominal segment a muscle arises, which is inserted into the floor of the pericardium; it is a narrow, flat, almost transparent mass of muscular fibre, called by M. Milne-Edwards “brides transparentes,” and not recognized by him as composed of muscular tissue. These are the *veno-pericardiac* muscles. Besides the six pairs in the abdomen, two pairs occur on each side of the thoracic entochondrite (Pl. LXXV. fig. 2).

DESCRIPTION OF PLATES LXXII. to LXXVI. (illustrating *Limulus*).

References.

<i>a.</i> Chitinous sclerite on the anterior plate of a mesosomatic appendage.	<i>ab.</i> Anterior border of an entocoxite.
<i>Ab.</i> Anterior thickened border of the meso-metasomatic carapace.	<i>A.c.en.</i> Anterior cornu of the entosternite or plastron: the proplastral process.
	<i>Al.</i> Alimentary canal.

- Ap.* Aperture leading to the space between the two plates forming a mesosomatic appendage.
- ar.* Anterior process of the mesosomatic sternite.
- c.* Chitinous bar in mesosomatic appendage.
- Ca.* Canal in the side wall of the mesosoma.
- Cam.* Camerostome (chitinized upper lip).
- Con.* Convexity of the lateral region of the prosoma.
- cp.* Coxal pivot.
- d.c.en.* Dorsal process of the plastron, or dorsal metaplastral process.
- Ec* or *ec.* Entapophysial ligament.
- Ect.* Cut portion of the same ligament.
- Encx.* Entocoxite.
- Ent¹-Ent⁷.* The seven entapophyses.
- gd.* Genital duct.
- gp.* Genital pore.
- il.* Inner lobe of a mesosomatic appendage.
- Int.* Intestine.
- K.* "Knob" of entocoxite, to which the tergo-coxal muscle is attached.
- L.* Liver and genital organ.
- l.* Lamellæ, forming the "gill-book" of a mesosomatic appendage.
- lat. scl.* Lateral sclerite.
- l.c.en.* Lateral cornu of plastron, or proplastral cornu.
- l.p.c.en.* Latero-posterior process of plastron, or lateral metaplastral process.
- M.* Mouth.
- mb.* Membrane of attachment of the pygal muscles.
- m, n, o, p, q, r, s, t, y, z.* Portions of the plastro-coxal muscles 32-44.
- ml.* Median lobe of a mesosomatic appendage (part of the sternal wall produced).
- mst.* Mesosomatic tergite.
- mtst.* Metasternite or "chilaria."

- N.* Network of chitin on the inner surface of the carapace.
- Na.* Angle of the posterior carapace belonging to metasomatic area.
- O.* Aperture of the branchial blood-vessel into the venous collecting sinus.
- œ.* Oesophagus.
- Ol.* Outer lobe of a mesosomatic appendage.
- P.* Plastron or thoracic entosternite.
- p.* Chitinous sclerite on mesosomatic appendage.
- p.ab.st.* Postabdominal, or metasomatic sternite.
- Pb.* Posterior border of the thoracic carapace.
- pb.* Posterior border of an entocoxite.
- Pe.* Pericardium.
- p.c.en.* Posterior process of the plastron or lateral metaplastral process.
- p.m.st.* Pro-sternite.
- pr.* Posterior process of a mesosomatic entochondrite.
- prs.* Prosomatic sternite.
- PT.* Metasomatic tergite.
- R.* Rectum.
- r.* Ventral ridge of a mesosomatic entochondrite.
- Ri.* Ridge on the inner surface of the thoracic carapace.
- S.* Muscular stomach.
- s¹-s⁹.* Mesosomatic entochondrites.
- Sf* or *sf.* Subfrontal sclerite.
- sfa.* Subfrontal area.
- sp.* Postanal spine or "pygō" (πυγή).
- sty.* Aperture (stigma) leading into the hollow tendon of a branchio-thoracic muscle.
- T.* Tergite.
- ts-ts^{vi}.* The hollow tendons of the branchio-thoracic muscle.
- Ve* or *ve.* Venous collecting sinus.
- W.* Wall of mesosoma.
- X.* Portion of mesosomatic sternite.
- x.* Point of attachment of mesosomatic appendage.

References to *Muscles*.

1. Dorsal entapophysio-plastral.
2. Ventral entapophysio-plastral.
3. Ventral longitudinal.
4. Inter-entapophysial.
- 4 a. Muscle from first to second entapophysis.
- 4 b. From first to third entapophysis.
- 4 c. From first to fourth entapophysis.
- 4 d. From first to fifth entapophysis.

5. Intersternal.
6. Internal tergo-pygol.
7. Middle tergo-pygol.
8. External tergo-pygol.
9. Ventral entapophysis-pygol.
10. Internal sterno-pygol.
11. External sterno-pygol.
12. Vertical mesosomatic ("transverse abdominal" of Milne-Edwards).
13. }
14. }
15. } Mesosomatic oblique entapophysis-sternal.
16. }
17. }
18. Branchio-thoracic (Milne-Edwards).
19. A slip from 18 to the second entapophysis.
20. External branchial.
21. Anterior entapophysis-branchial.
22. Posterior entapophysis-branchial.
23. Pre-entapophysis-branchial.
24. Tergo-coxal of the first prosomatic appendage.
25. Tergo-coxals of the succeeding appendages.
 - 25 *a*. Tergo-coxal of second appendage.
 - 25 *b*. Tergo-coxal of third appendage.
 - 25 *c*. Tergo-coxal of fourth appendage.
 - 25 *d*. Tergo-coxal of fifth appendage.
 - 25 *e*. Tergo-coxal of sixth appendage.
26. Antero-superior tergo-coxal.
27. Antero-inferior tergo-coxal.
28. Postero-superior tergo-coxal.
29. Postero-inferior tergo-coxal.
30. Anterior plastro-coxal of first appendage.
31. Posterior plastro-coxal of first appendage.
32. Second superior plastro-coxal.
 - m*, its anterior slip (to anterior border of entocoxite).
 - n*, its posterior slip (to posterior border of entocoxite).
33. Second mid plastro-coxal.
34. Second inferior plastro-coxal.
35. Third superior plastro-coxal.
 - o*, its anterior slip.
 - p*, its posterior slip.
36. Third mid plastro-coxal.
37. Third inferior plastro-coxal.
38. Fourth superior plastro-coxal.
 - q*, its anterior slip.
 - r*, its posterior slip.
39. Fourth mid plastro-coxal.
40. Fourth inferior plastro-coxal.
41. Fifth superior plastro-coxal.
 - s*, its anterior slip.
 - t*, its posterior slip.
42. Fifth mid plastro-coxal.
43. Fifth inferior plastro-coxal.
44. Sixth antero-superior plastro-coxal.
45. Sixth mid plastro-coxal.
46. Sixth antero-inferior plastro-coxal.
47. Sixth postero-inferior plastro-coxal.
48. Internal branchial.
49. }
50. } Three tergo-proplastrals.
51. }
52. Dorso-lateral plastro-tergal.
53. Dorso-lateral plastro-entapophysial.
54. Anterior mesoplastro-entapophysial.
55. Posterior mesoplastro-entapophysial.
56. Dorsal metaplastro-entapophysial.
57. First lateral proplastro-tergal.
58. Superior second lateral proplastro-tergal.
59. Inferior second lateral proplastro-tergal.
60. Sixth postero-superior plastro-coxal.
61. Meso-metasomatic sternal.
62. }
63. } Mesosomatic inter-sternals.
64. }
65. Chilarial.
66. Gastro-sternal.
67. Plastro-buccal.
68. Veno-pericardiac (pericardio-ventrals).
69. A slip from the ventral longitudinal (3) to the second abdominal sternite.
70. A slip from 3 to third abdominal sternite.
71. A slip from 3 to fourth abdominal sternite.
72. Vertical entapophysis-metaplastral.
73. Middle entapophysis-plastral (part of 2).
74. Slip from 3 to fourth entapophysis.
75. Slip from 3 to fifth entapophysis.
76. Slip from 3 to sixth entapophysis.
77. Slip from 3 to seventh entapophysis.
78. Intertergal.
83. Slip from 1 to third entapophysis.
84. Slip from 1 to fourth entapophysis.
85. Slip from 1 to fifth entapophysis.
86. Slip from 1 to sixth entapophysis.
87. Termination of 1 in seventh entapophysis.

88. Mid-ventral entapophysio-pygal.
89. Externo-ventral entapophysio-pygal.
90. Interno-ventral entapophysio-pygal.
91. Externo-dorsal entapophysio-pygal.
92. Mid dorsal entapophysio-pygal.
93. Interno-dorsal entapophysio-pygal.
94. Internal sternal slip from 7 (a tergo-pygal).
95. External sternal slip from 7 (a tergo-pygal).
96. Internal sternal slip from 8 (a tergo pygal).
97. External sternal slip from 8 (a tergo-pygal).
103. A slip from 73 to the third entapophysis.
104. A slip, partly from 2 and partly from 73 to fourth entapophysis.
105. A slip from 2 to fifth entapophysis.
106. A slip from 2 to sixth entapophysis.
107. Terminal portion of 2 (the ventral entapophysio-plastral).
112. Muscle from a sclerite (*p*) on mesosomatic appendage to the outer lobe of the same.
113. A slip from 20 to sclerite (*a*) on the mesosomatic appendage.
114. A muscle from sclerite (*p*) on mesosomatic appendage to the inner lobe of the same.
115. A slip from 48 to sclerite (*p*) on the mesosomatic appendage.
- I.-VI. Prosomatic appendages.
- VII.-XII. Mesosomatic appendages.
- VII *a*. Immovable spine belonging to the first mesosomatic segment.
- VIII *a*.-XIII *a*. Movable spines corresponding to the last five segments of the mesosoma and the first of the metasoma.

PLATE LXXII.

The floor of the animal (natural size) after removal of muscles and viscera. It shows the raised subfrontal area (*sfa*), the great arching of the chitinous floor at the sides (*cen*), whilst along the line of attachment of the appendage there is a nearly vertical dip; the walls of this hollow being formed by the entocoxites and the intervening membrane. In the middle of the prosoma or thorax is seen the cut œsophagus (*œ*), in front of this the camerostome (*cam*), and behind it the "promesosternite"; behind these again are seen a pair of cavities leading into the chilaria (metasternite). The transverse hollows (VII-XII) in the mesosomatic floor are the entrances to the spaces between the plates of the mesosomatic appendages; the hollow tendons (*ts*) of the branchio-thoracic muscles are seen. On the post-abdominal sternal region (*p.ab.st*) are seen the areas of attachment of some of the pygal muscles. Behind this is the cut rectum, and then the post-anal spine or "pyge." On the left the wall of the mesosoma has been cut away to show the canal (*ca*), which runs forwards to the front part of the mesosoma, and holds blood-vessels and nerves.

PLATE LXXIII.

The carapace and heart have been removed, and the alimentary canal. Fig. 1 is a more superficial dissection than fig. 2.

Fig. 1. On the right side the dissection is more superficial than on the left: the tergo-coxals (24, 25) are seen attached to the "knob" of the entocoxites. That of the first appendage (24) is seen nearer the middle line than the rest.

Various plastro-entapophysial muscles are shown attached to the first entapophysis. One sees the inter-entapophysial muscles (4) passing from one entapophysis to the other, the tergo-pygals (6, 7, 8) and entapophysio-pygals (91, 92, 93), the external branchials (20), the small veno-pericardiacs (68) passing outwards and upwards across the intersternals. The larger vertical abdominals (12) also pass across the intersternals. Besides these the cut bases of the entapophyses are shown, and connecting these the inter-entapophysial cartilages (*ec*); and at the sides of the anterior part of the figure are the lateral cornua of the plastron with their muscles 57, 58.

On the left side of the figure the liver and genital organ have been removed, so as to expose the body of the entosternite or "plastron" (P) and its dorsal process. The dorsal entapophysio-plastral (1) is now seen passing across the vertical muscles, and giving off various slips to the entapophyses. The pygal muscles and the cartilaginous band have been removed.

Fig. 2. On the left side the dissection is more superficial than on the right: the course of the dorsal entapophysio-plastral muscle is more completely shown, the inter-entapophysials having been removed. The anterior cornua of the plastron (*A.c.en*), with their muscles (49, 50, 51), are also seen; and posteriorly the sterno-pygals (10, 11) and entapophysio-pygals (88, 89, 90). The abdominal sternites (s^1-s^6) lying on the floor of the mesosoma are also exposed.

On the right side of the figure the above-named muscles have been removed, so as to show the course of the ventral entapophysio-plastral muscles (2 & 73) with their slips to the entapophyses. The entapophysio-metaplastrals have been cut, so as to show the posterior median process of the plastron (*p.cen*).

PLATE LXXIV.

Fig. 1. All the overlying muscles have been removed, and thus the floor of the animal is exposed. On the right the distribution of the ventral longitudinal (3) and the intersternal muscles (5) is seen. The slips passing from the various sternites to the entapophyses, and the vertical muscles (12) inserted in the abdominal sternites are also seen.

On the left the aforementioned muscles have been removed in order to show the venous-collecting sinus (*Vc*) lying at the side of the floor of the animal, passing anteriorly above the plastron, where it has been cut. The veno-pericardiac muscles (68) are shown springing from this canal, and are turned towards the middle line. Passing up at the side of the canal are shown the hollow tendons of the branchio-thoracic muscles (18), each ending anteriorly in a muscular portion, which has been cut. Attached to the side of each abdominal entochondrite is seen a small muscle (48), the internal branchial.

Outside the canal are seen the various branchial muscles rising from the mesosomatic appendages to their attachment in that portion of the entapophysial ligament (*ec*) which partly embraces each entapophysis.

Fig. 2. A portion of the venous-collecting sinus, removed and enlarged; in front the wall has been cut to show the apertures (O) of the descending vessels to the mesosomatic appendages. The hollow portions of some of the branchio-thoracic muscles (18) are seen uniting to form the large muscular portion. Some of the branchial muscles are also seen.

Fig. 3. Two mesosomatic appendages seen from below.

VIII. The deep face of the anterior plate of the eighth appendage. The appendage is turned forwards. The posterior plate—except the portions which bear the gill-lamellæ (*l*), and the “stigmata” (*stg*) leading into the hollow tendons of the branchio-thoracic muscles—has been dissected away.

IX. is the inner face of the posterior plate of the ninth appendage, after removal of the anterior face. At the base of each appendage is an abdominal sternite (*s*) with muscles passing in various directions from it. The second pair of entapophyses (*ent. 2*) are seen with a portion of the entapophysial ligament (*ec*), to which some of the branchial muscles (21, 22, 23) are attached. Various sclerites (*a.p.c*) with their muscles (23, 48, 112, 113, 114, 115) are also seen, which lie on the surface of the appendages. The tendons (*ts*) of the branchio-thoracic muscle are shown.

Fig. 4. Inner surface of posterior plate of the seventh appendage, “genital operculum.” The genital duct (*gd*) cut short is seen.

Fig. 5. Inner surface of anterior plate of the genital operculum. The stigmata (*stg*) of the basal portion (*ts*) of the branchio-thoracic muscle. The genital duct and aperture (*gp*), and the first pair of entapophyses are shown.

PLATE LXXV.

Longitudinal sections.

Fig. 1. Shows two entocoxites (*Encx*) with their muscles (25): the camerostome and basal part of first appendage and its muscle (24): the entosternite or plastron (P) and its muscles (49, 50, 51, 52, 53): the course of the branchio-thoracic muscle (18) with its hollow tendons (*ts*) and their apertures (*stg*): the pygal muscles, attached partly to the tergum of the metasoma and partly to the hinder entapophyses (6, 7, 90, 91, 92). A few only of the branchial muscles (20, 22, 23) and two of the vertical mesosomatic muscles (12) are represented. This figure also shows the claw-like termination of the second appendage (II) characteristic of the male *Limulus polyphemus*. The other prosomatic appendages have been cut short.

- Fig. 2. Shows the relation of the pericardium (*Pe*) and the venous collecting sinus (*vo*) to the other parts and to one another. To be especially noticed are the pericardio-ventral or veno-pericardiac muscles (68): the vertical mesosomatic muscles (12): the ventral pygal muscles (9, 10, 11): the muscular stomach (*s*) with its muscle (66) to the subfrontal area (*sfa*). Also the intertergal muscle (78) flexing the abdominal upon the thoracic region.
- Fig. 3. Shows the plastro-tergal muscles (49 to 54): the genital duct in appendage VII: the inter-entapophysial muscles (4): the course of the ventral longitudinal (3) and intersternal muscles (5), with their various slips to the entapophyses. Also the vertical abdominals (12).
- Fig. 4. External view of two entapophyses of the left side (twice nat. size) showing the cartilaginous interentapophysial ligament (*ec*) swelling out to partly embrace the entapophysis, and serving for the attachment of various muscles which pass to the mesosomatic appendages. The area of attachment of two of the external branchial muscles (20) is shown.
- Fig. 5. Internal view (mediad face) of two entapophyses of the right side (twice nat. size). The cartilaginous interentapophysial ligament is seen, and various muscles attached to the entapophysis itself. Also the area of attachment of two of the vertical mesosomatic muscles (12) is seen on the tergite.
- Fig. 6. A three-quarter view from in front and within of an entapophysis and cartilage.
- Fig. 7. A three-quarter view from behind and without, showing the cut end (*ect*) of that part of the inter-entapophysial ligament that passes from one swelling to another. The swelling of the ligament is deeply cupped and fixed to the chitinous entapophysis. It contains a core of capsuligenous tissue, whilst the rest of the ligament consists of fibro-massive tissue.

PLATE LXXVI.

- Fig. 1. Inner face of the prosomatic and mesosomatic carapaces, showing the areas of attachment of the various tergal muscles. [Unfortunately this figure is very inaccurate and incomplete in respect of the areas of muscular attachment, and must not be relied upon in that matter.—E. R. L.] On the right half the areas are left uncoloured, and are more plainly limited than on the left half. The entapophyses are shown, and the ridge (*ri*) on each side, corresponding to a depression on the exterior. The lateral parts of the terga have a chitinous network raised upon their inner surface. In the mesosomatic portion is shown a part (*x*) of the sternal region which rises to meet the tergite.
- Fig. 2. Shows the relative positions of the entocoxite (whose knobs (*k*), to which the tergo-coxals are attached, are seen), the prosomatic entochondrite (plastron) (*P*), and the mesosomatic entochondrites (*s*). The hollow tendons (*ts*) of the

last pair of branchio-thoracic muscles are seen, rising from the front edge of the metasomatic sternite (*p.ab.st*).

- Fig. 3. Ventral view of the plastron or thoracic entochondrite, after all muscles have been removed.
- Fig. 4. View of the dorsal face of the plastron, with the various plastro-tergal and plastro-entapophysial muscles &c.
- Fig. 5. Dorsal view of the plastron, the left edge cut away to show the plastro-coxal muscles (32-44) entering the entocoxites. (The dorsal process (*d.c.en*) is represented as rather too rounded at the top.)
- Fig. 6. Ventral view of the plastron, with the various plastro-coxal muscles attached on the observer's right.
- Fig. 7. An entocoxite, being the inner articular surface of a prosomatic appendage. It is made up of an anterior (*ab*) and a posterior (*pb*) border, and superiorly of a knob (*k*) to which the tergo-coxal (25) is attached, and of a coxal pivot (*cp*), by which the appendage is articulated with the sternal plate of the carapace.
- Fig. 8. A mesosomatic entochondrite seen from below.
- Fig. 9. A mesosomatic entochondrite from in front (represented with its ventral face upwards).
- Fig. 10. A transverse section across the mesosoma (from C to D, Pl. LXXII.), showing the thick wall, with a canal within it. The sternal region rises to meet the tergal, and leaves but a narrow membranous area for the attachment of the appendage (*x*), which has been removed.
- Fig. 11. A transverse section across the metasoma (from A to B, Pl. LXXII.), showing complete chitinous floor (*p.ab.st*).
-

Con

Sta

Stroma. 2000. Pl. VI. 172

C

A

Ca

II

III

Pabst

R

sp

VII^a

D

B

VIII^a

IX^a

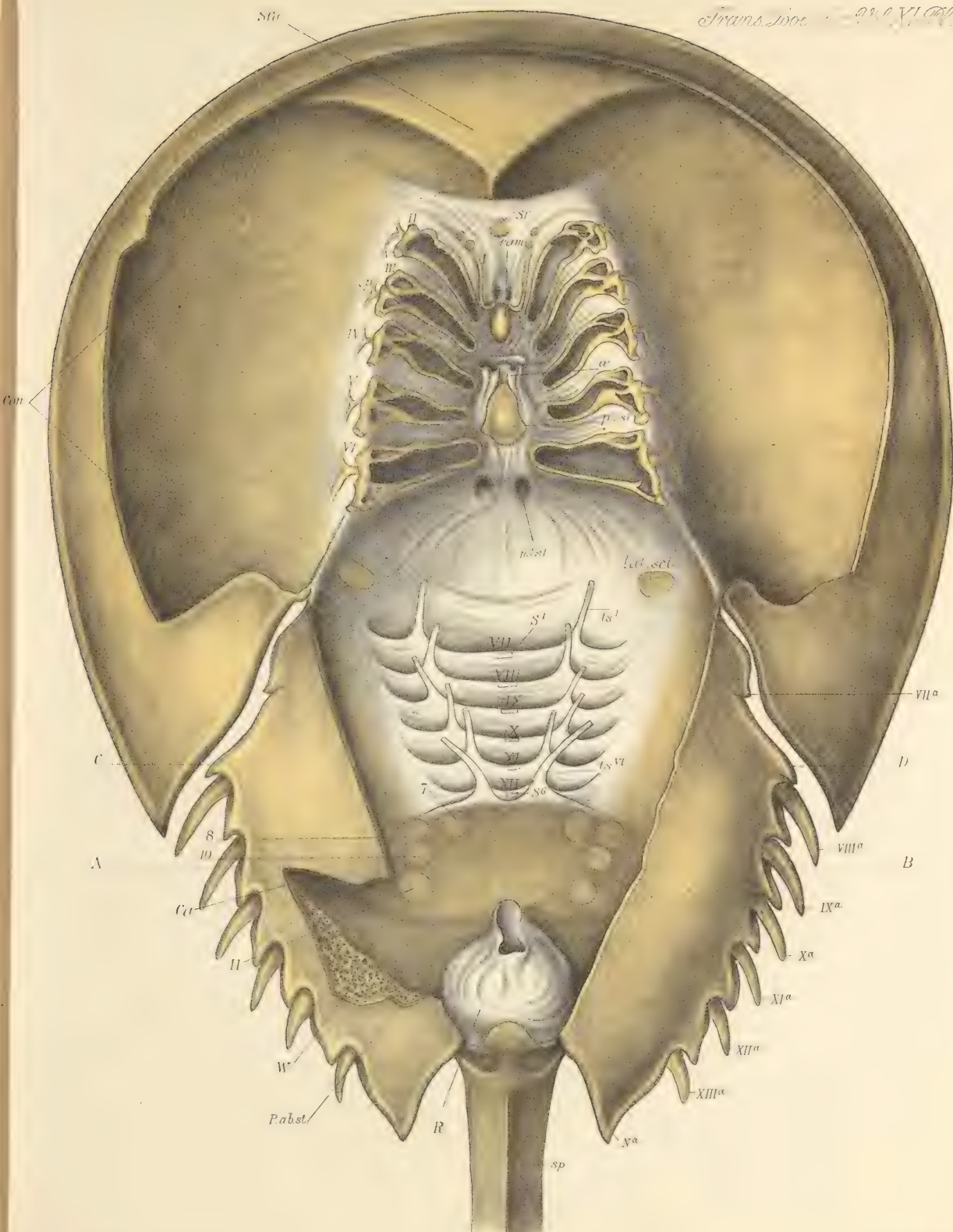
X^a

XI^a

XII^a

XIII^a

X^a



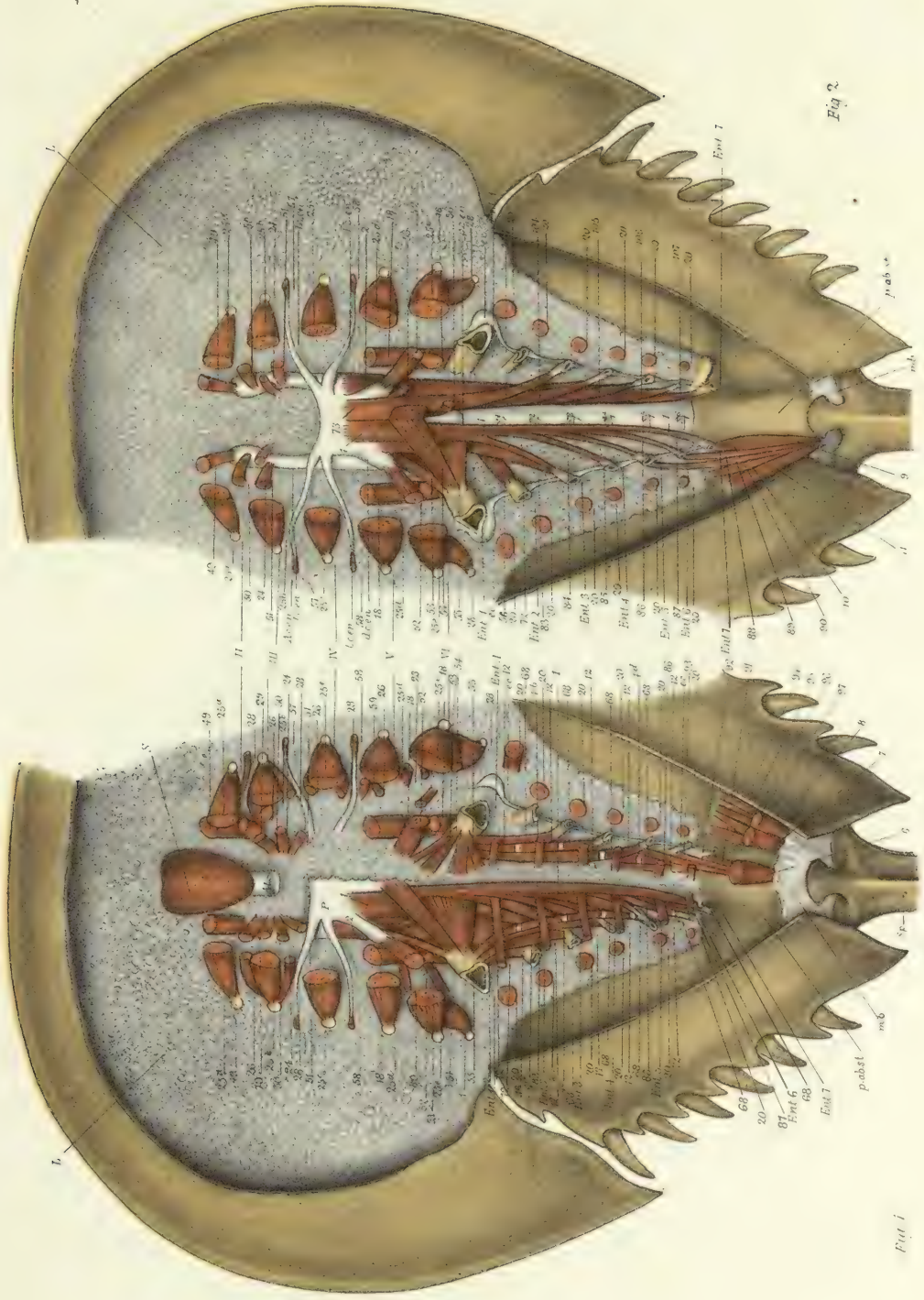
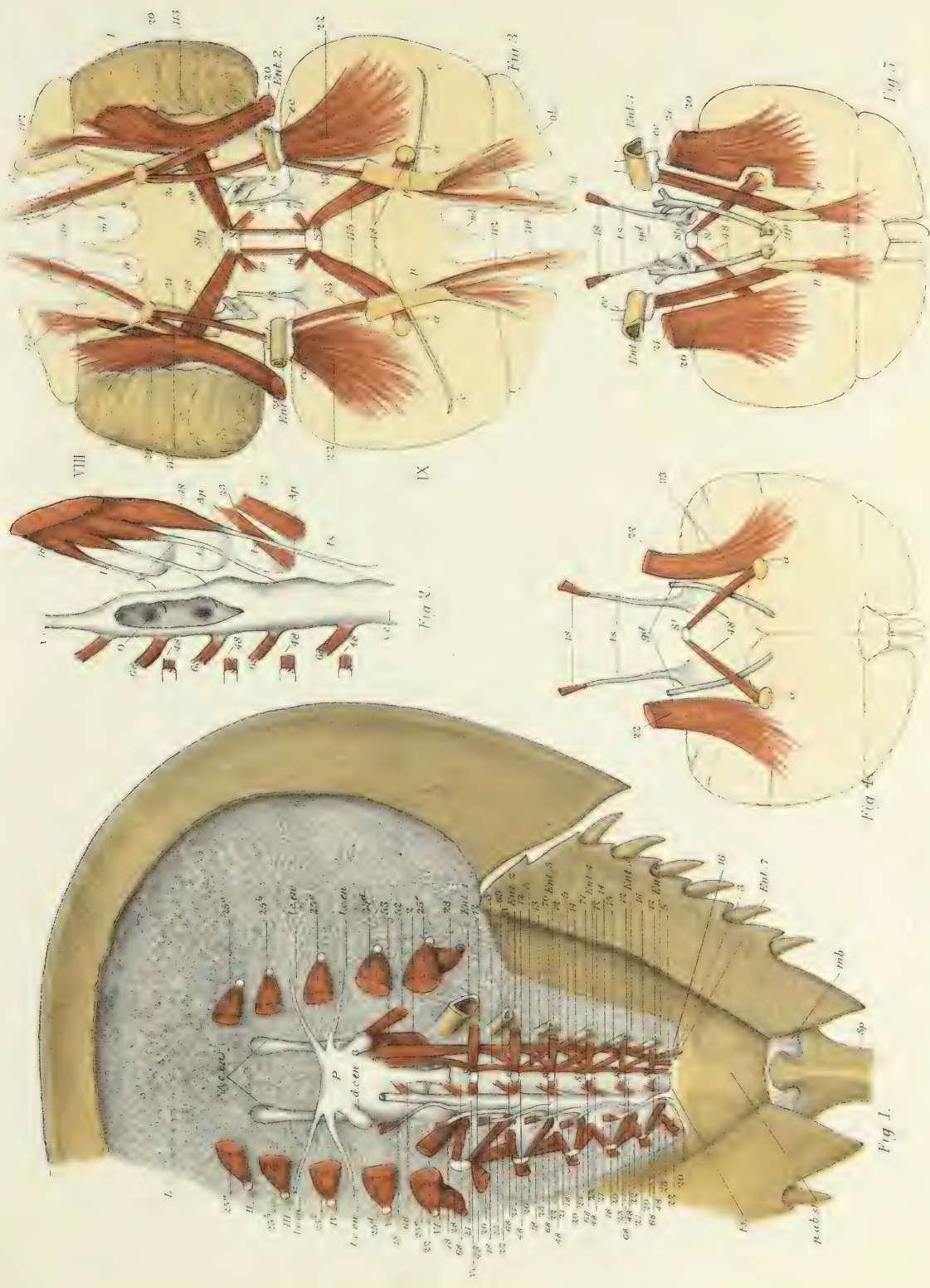


Fig 2

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APPENDIX OF UNITS

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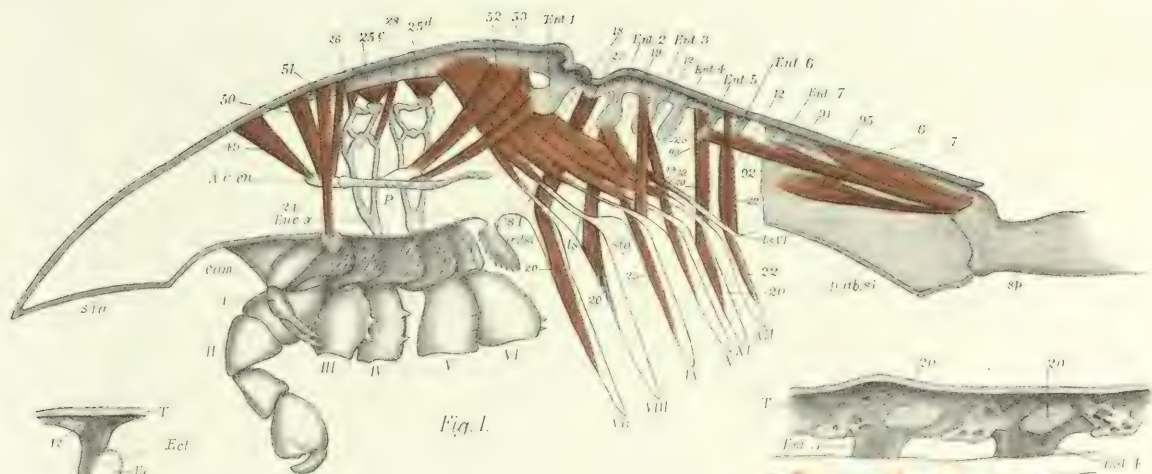


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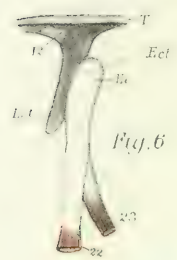


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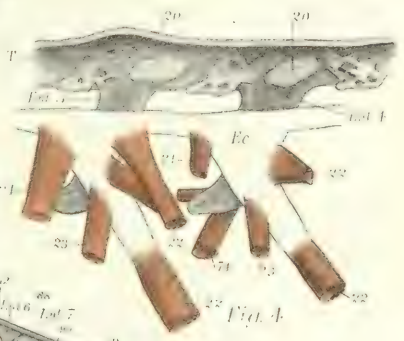


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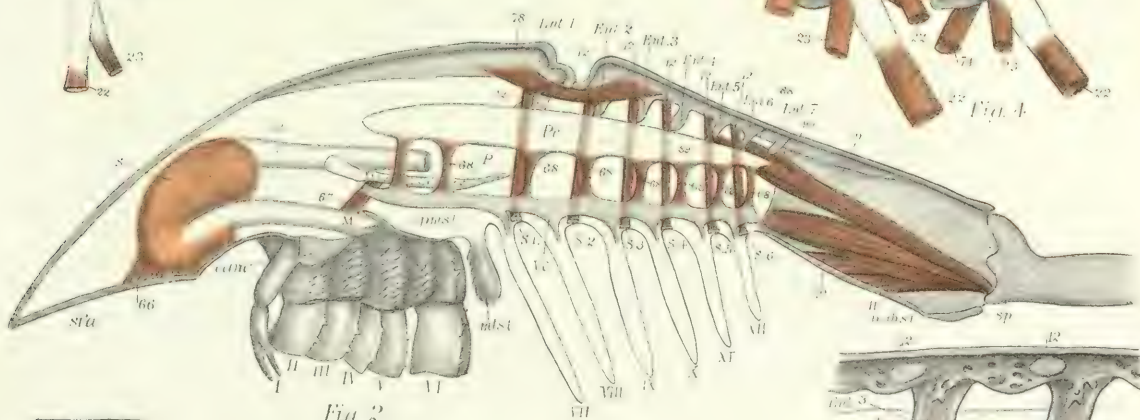


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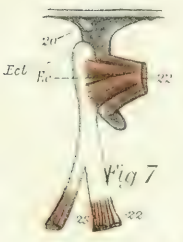


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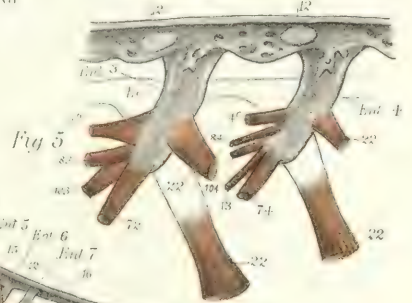


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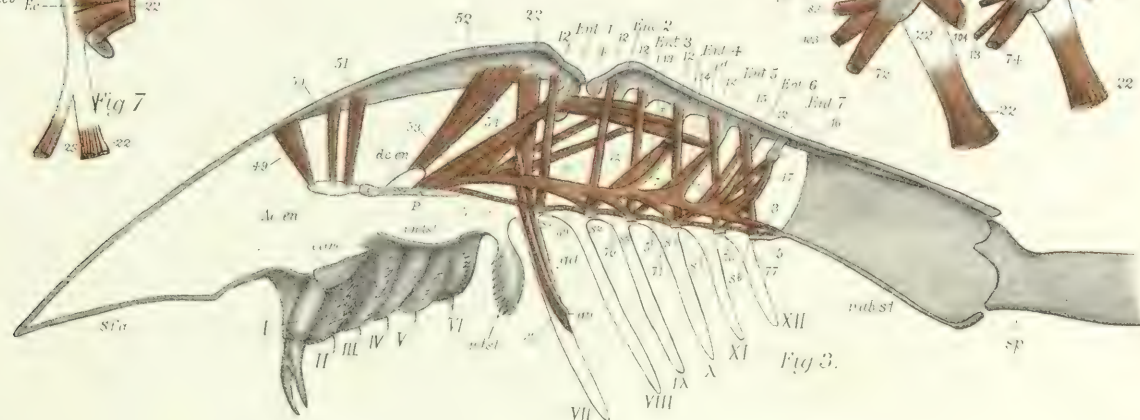


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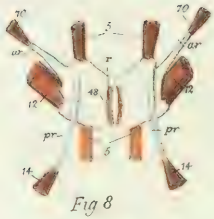


Fig. 8.



Fig. 9.



Fig. 1.



Fig. 7.

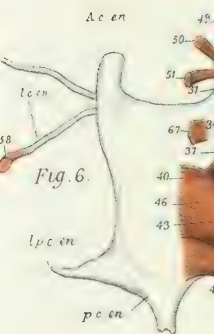


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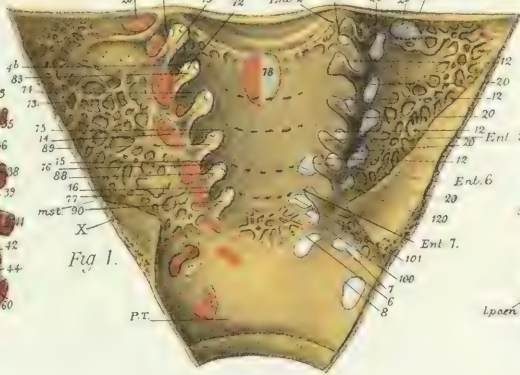


Fig. 1.



Fig. 4.

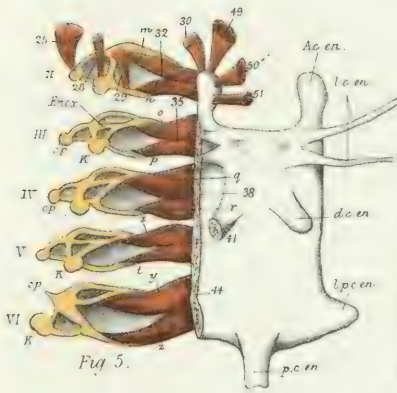


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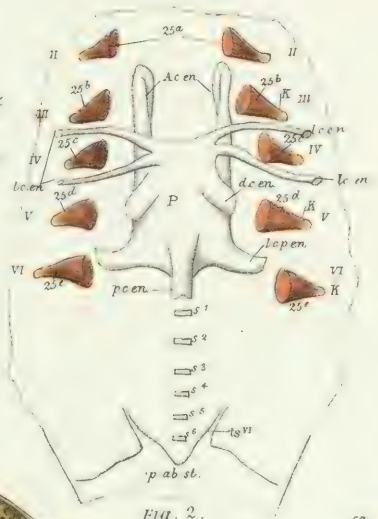


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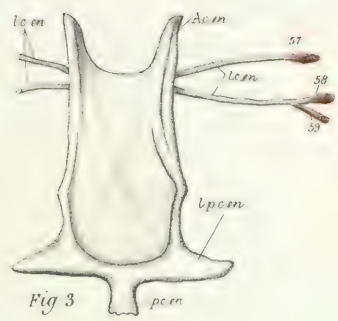


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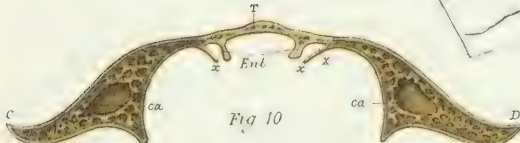


Fig. 10.



Fig. 11.

PART III. *Description of the Muscular and Endoskeletal Systems of Scorpio.*

By Miss E. J. BECK.

FOR this work, in which I have been assisted by the kind supervision of Professor Lankester, I have used the Ceylon Scorpion (*Buthus cyaneus*) for dissecting, whilst I have also referred to a series of sections of the small Scorpion (*Scorpio italicus*), by means of which I have been able to find some small muscles which I should have otherwise passed unnoticed, and some which are too small to be seen by the naked eye.

I have named the muscles as much as possible from the names of the two points to which they are attached. Thus in many cases the names are long and awkward. In order to somewhat modify this difficulty I have given to each muscle a separate number, and have numbered them similarly in the figures.

It must be remembered that each of the muscles which I shall mention is repeated in a corresponding position on the opposite side of the animal, with the exception of a few which are situated in the median line, and which I shall particularly point out.

Before giving a description of the muscles of the Scorpion it will be necessary to examine the general form of the animal, and more particularly its skeleton, external and internal, with any other parts that form attachments for muscles.

External Skeleton.—The body of the Scorpion may be divided into three parts, the prosoma, mesosoma, and metasoma, each of which represents six segments, and corresponds precisely to the similarly named part in the King Crab. The segments are indicated partly by sclerites and partly by appendages. Following the metasoma is the postanal spine or sting.

Dorsal Sclerites.—The whole of the dorsal surface of the prosoma is covered by one large chitinous plate, the cephalothoracic plate or carapace (*car*). This is followed by seven wide sclerites, six of which represent the six segments of the mesosoma (VII–XII), whilst the seventh (XIII) belongs to the first segment of the metasoma, and is fused towards its posterior end to a corresponding sclerite on the sternal surface. Posteriorly this sclerite becomes narrower, and is followed by five narrow cylindrical sclerites (XIV–XVIII), which are formed by the fusion of the tergite of the dorsal surface with the sternite of the ventral.

Appendages and Sternal Sclerites.—On the ventral surface of the prosoma there are six leg-like appendages, which indicates that six segments have coalesced to form the carapace.

The first appendage, chelicera (1), is small, consisting of three sclerites: the proto-merite or coxa, the deutomerite, and the tritomerite. The deutomerite is drawn out, and forms with the tritomerite a pincer. This pair of appendages is situated in front of the mouth and projects anteriorly.

The second appendage, chela (ii), is large and composed of six sclerites. As in the first appendage the penultimate sclerite forms with the last a powerful chela; between the coxal sclerites of this pair is the remarkable upper lip, the camerostome (*cam*), on the dorsal surface of which is a small chitinous sclerite.

The third and following appendages of the prosoma each consist of seven sclerites and two small terminal claws; these appendages are the walking-legs.

On the coxal joints of the second, third, and fourth appendages there are small processes which meet in the median line and assist the mouth as mandibular organs; these are the "sterno-coxal processes." The coxal joint of the fifth appendage is fused to that of the sixth, and is immovable without it.

To the sterno-coxal process of the third appendage is attached a movable "epicoxite" similar to the pieces so named on limbs 2, 3, 4, and 5 of *Limulus*¹.

The coxal sclerites of the second, third, and fourth appendages of one side meeting those of the other side in the median line have almost obliterated the sternite of the prosoma; all that remains is a small pentagonal sclerite situated in the median line between the coxal joints of the fifth and sixth appendages of either side. This is called the "thoracic metasternite" (*met*), and is the exact equivalent of the chilaria of *Limulus*. (See Lankester, *loc. cit.*)

The appendages of the mesosoma are much modified. In an early state of development a rudimentary pair of appendages appears on each of the six segments. These afterwards disappear from view, with the exception of the first and second pairs. The first pair are simply small plates which together form the genital operculum (*go*) as in *Limulus*. The second pair, the pectines (*pec*), are carried on a small sternal sclerite, and are comb-like organs with a number of lamellæ set on their inferior margin.

On the sternal surface of the four last segments there are wide sclerites which apparently carry no appendages; on closer examination two stigmata will be seen on each sclerite; these lead into small sacs, which are, according to Professor Lankester, nothing more or less than the appendages themselves invaginated, that is, completely pushed outside in. The appendages are composed of an axis, on which are set a number of lamellæ, like the pages of a book; they perform the function of respiration, and exactly represent the four posterior branchial appendages of *Limulus* in an introverted condition.

The six sternal sclerites of the metasoma have been mentioned above as fused to the tergites, and as being, in the last five segments, of a cylindrical form. These segments carry no appendages.

For a more detailed description of the skeleton of the Scorpion the reader is referred to a paper by Prof. E. Ray Lankester, "*Limulus* an Arachnid" (*Quart. Journ. of Micr. Science*, 1881).

[¹ The epicoxites of *Limulus* and *Scorpio* appear to be similar in character to the rudimentary second ramus of the limbs of *Scolopendrella* and other forms noted by Wood-Mason.—E. R. L.]

Arthrodial Membrane.—The lateral part of the body and all the interspaces between the sclerites are covered with a flexible membrane, the “arthrodial membrane” (*am*).

Internal Skeleton.—The internal skeleton may be divided into two parts, the entosclerites and the entochondrites. The entosclerites are epidermal in origin, and are really only ingrowths of the external skeleton; they may be divided into two kinds, the coxal entosclerites, which are internal processes of the coxal sclerites of the appendages, and the median entosclerites, which are continuous with the external skeleton in the median line. The entochondrites are fibro-cartilaginous pieces which are freely movable, not being fixed to any chitinous parts of the skeleton, and only attached to them by fibrous tissue and muscles. They form a strong point of attachment for muscles, which radiate from them to the appendages, tergites, and other parts of the body. These skeletal pieces have been formed by a condensation of connective tissue.

Fig. 1.

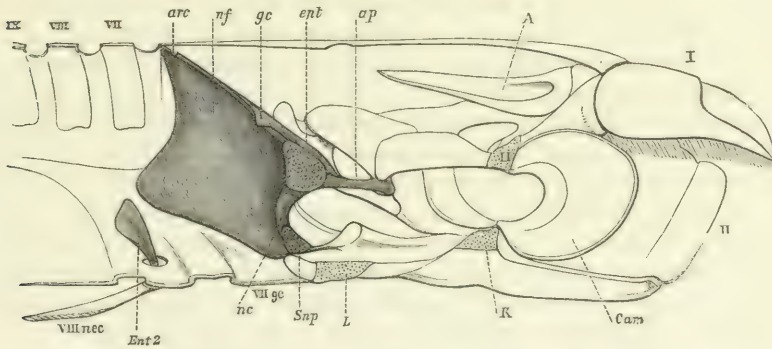


Fig. 1. Diagrammatic view of the anterior portion of a Scorpion (*Buthus*) divided along the median longitudinal line, all the soft parts being removed so as to show the relations of the entosclerites (ingrowths of the epidermic cuticle) and the entochondrite, which is alone shaded. (Compare Pl. LXXIX. fig. 15.)

I, chelicera; II, second appendage (chela); VII, VIII, IX, tergal sclerites of the seventh, eighth, and ninth segments; A, coxal entosclerites of the chelicera; H, preoral entosclerite; K, postoral entosclerite; L, carino-sternal entosclerite; Cam, camerostome (upper lip); VII gc, sternal region of the genital segment; VIII nec, pecten; ap, left anterior process of the great entochondrite attached to the left arm of preoral entosclerite; ent, body of the great entochondrite; Sup, subneural arch of the same; nc, neural canal of the entochondrite; gc, gastric canal of the entochondrite; nf, posterior flap or fibrous expansion of the entochondrite spread out as a diaphragm across the body; arc, arterial canal; Ent², second entochondrite (suprapetinal).

Coxal Entosclerites (Pl. LXXIX. figs. 15, 16).—The coxal entosclerites are called either anterior or posterior, according to the portion of the interior margin of the coxal sclerite on which they are situated.

In the first appendage the posterior portion of the coxal sclerite is drawn out into a narrow and long process (A), which extends backwards and gradually tapers to a point.

In the second appendage the anterior margin of the coxal sclerite presents on its inner face a small process (B) which points down towards the posterior margin of the same sclerite.

In the third appendage the coxal sclerite is drawn out internally into a process on both the anterior and posterior margins. That on the anterior (C) is very small and is near the median line; that on the posterior (D) is large and is situated laterally.

In the fourth appendage there are also two internal processes on the coxal sclerite, the one anterior, the other posterior. The anterior process (E) is larger than that of the third appendage and has a more lateral position. The posterior process (F) is similar to that of the third, and is lateral.

In the fifth appendage there is a small process (G) on the anterior margin of the coxal sclerite, which is quite lateral and behind the posterior process of the fourth appendage. There is no process on the posterior margin of this sclerite.

The coxal sclerite of the sixth appendage carries no process on either margin.

Median Entosclerites.—In the median line anterior to the mouth is situated an entosclerite (H), to the anterior portion of which the superior portion of the coxal sclerite of the second appendage is articulated. From either side of this anterior portion there is a lateral process which runs posteriorly in a horizontal plane. It is marked in fig. 16, Pl. LXXIX., by the figures appropriate to muscles which are attached, viz. 95, 96, 97. This entosclerite may be called the "preoral entosclerite."

A small entosclerite (K) is situated in the median line close behind the mouth; on it the inferior portion of the second appendage, and the third and fourth appendages, are articulated. This may be called the "postoral entosclerite."

Posterior to this in the median line lies the pentagonal thoracic metasternite, on the internal surface of which is a narrow process (L) standing up in the middle line. This process soon forks and ends anteriorly to the genital operculum. This may be called the "carino-sternal entosclerite."

The Plastron (Pl) or Prosomatic Entochondrite (Entosternite of Lankester, *loc. cit.*).—Towards the posterior part of the prosoma, between the cephalothoracic plate and the sternal surface, is situated the plastron (Pl. LXXX. fig. 13). The alimentary canal passes through it in a canal (GC) which lies between two dorsal ridges running on the dorsal surface from the anterior to the posterior portion. The nerve-cord also runs through a canal (NC) in the plastron, and thus forms a subneural portion (Pl. LXXX. fig. 14, *snp*) on the ventral side. The anterior aorta also perforates the plastron by the canal AC. The muscles 65 and 83 also perforate the lateral regions of the plastron. This entochondrite is not fixed to any of the chitinous skeletal pieces, except by muscles and fibrous tissue. At its posterior end there is a large posterior flap (*pf*), which is

attached ventrally to the posterior margin of the coxal sclerite of the sixth appendage, and dorsally to the arthrodial membrane between the carapace and the first tergite of the mesosoma; it forms a septum between the prosoma and the mesosoma (see wood-cut, fig. 1, and explanation). From the plastron there are several processes which are similar on each side. The anterior processes (*ap*) are long and run forwards; each at its anterior end (*a*) is attached by fibrous tissue to the ventral surface of the posterior end of the corresponding "cornu" of the preoral entosclerite. A lateral median process (*lmp*) starts from the side of the plastron and runs out laterally on each side. A posterior process (*pp*) runs from the posterior end of the plastron, being fused for part of its way with the fibrous flap. There is also a small pair of anterior processes on the subneural portion of the plastron, the "anterior subneural processes" (*asp*).

Suprapectinal Chondrite or Second or Mesosomatic Entochondrite.—There is a second and much smaller entochondrite in the segment of the pectines, which is a simple fibrous band lying ventral of the nerve-cord (as do the mesosomatic entochondrites of *Limulus*), to which several muscles are attached.

MUSCLES.

The muscles of the Scorpion may be classified as follows:—

- I. Longitudinal Muscles.
 - a.* Prosoma.
 - b.* Mesosoma.
 - c.* Metasoma.
- II. Dorso-Ventral Muscles.
 - a.* Prosoma.
 - b.* Mesosoma.
 - c.* Metasoma.
- III. Muscles attached to the Plastron.
- IV. Muscles attached to the Suprapectinal Entochondrite.
- V. Muscles attached to the Preoral Entosclerite.
- VI. Muscles attached to the Appendages.
- VII. Muscles attached to the Epimeron.
- VIII. Muscles attached to the Pharynx.
- IX. Muscles attached to the Pericardium.
 - a.* Mesosoma.
 - b.* Metasoma.

I. Longitudinal Muscles.

All the segments of the mesosoma and metasoma are moved on one another by longitudinal muscles. In the prosoma, however, as there is but one tergite, so there is but

one set of longitudinal muscles, which is situated in the posterior portion, and moves the carapace on the first segment of the mesosoma.

For the dorsal longitudinal muscles see Pl. LXXVII. fig. 2.

For the ventral longitudinal muscles see Pl. LXXVII. fig. 3.

a. *Prosoma*.

Dorsal.—The *antero-posterior muscle* (1) is a large muscle running parallel with the longitudinal median line. It extends laterally from the pericardium to the side of the animal. Anteriorly it is attached to the carapace, and posteriorly to the arthrodial membrane posterior to the carapace.

The *arthrodio-tergal obliquus muscle* (2) is smaller, and is attached posteriorly to the arthrodial membrane between the carapace and the first segment of the mesosoma. It is superficial to the antero-posterior muscle (1), and runs obliquely forward towards the median line, being attached anteriorly to the carapace.

Ventral.—There are no ventral longitudinal muscles in the prosoma.

b. *Mesosoma*.

Dorsal.—The *antero-posterior muscle* (3) of the first segment of the mesosoma runs parallel with the median line, stretching laterally from the pericardium to the side of the body. It is attached anteriorly and posteriorly to the arthrodial membrane, anterior and posterior to the segment.

The *antero-posterior muscle* (4) of the second segment of the mesosoma; the *antero-posterior muscle* (5) of the third segment of the mesosoma; the *antero-posterior muscle* (6) of the fourth segment of the mesosoma; the *antero-posterior muscle* (7) of the fifth segment of the mesosoma; and the *antero-posterior muscle* (8) of the sixth segment of the mesosoma, are exactly similar to the antero-posterior muscle (3) of the first segment of the mesosoma.

The *arthrodio-tergal obliquus muscle* (9) of the first segment of the mesosoma is attached posteriorly to the arthrodial membrane between the first and second segments. It is superficial to the antero-posterior muscle (3), and runs obliquely forward towards the median line, being attached anteriorly to the tergite.

The *arthrodio-tergal obliquus muscle* (10) of the second segment of the mesosoma; the *arthrodio-tergal obliquus muscle* (11) of the third segment of the mesosoma; the *arthrodio-tergal obliquus muscle* (12) of the fourth segment of the mesosoma; the *arthrodio-tergal obliquus muscle* (13) of the fifth segment of the mesosoma; and the *arthrodio-tergal obliquus muscle* (14) of the sixth segment of the mesosoma, are all similar in form and position to the arthrodio-tergal obliquus muscle (9) of the first segment of the mesosoma.

The *latero-dorsal muscle* (15) of the first segment of the mesosoma is attached at its

posterior end to the lateral portion of the arthrodial membrane at the posterior angle of the segment. It bends round to the tergite, to which it is attached.

The *latero-dorsal muscle* (16) of the second segment of the mesosoma; the *latero-dorsal muscle* (17) of the third segment of the mesosoma; the *latero-dorsal muscle* (18) of the fourth segment of the mesosoma; the *latero-dorsal muscle* (19) of the fifth segment of the mesosoma; and the *latero-dorsal muscle* (20) of the sixth segment of the mesosoma, are all similar in form and position to the latero-dorsal muscle (15) of the first segment of the mesosoma.

Ventral.—The *median antero-posterior muscle* (21) of the third segment of the mesosoma runs along the median line from the arthrodial membrane anterior to the sternite, to the arthrodial membrane posterior to the sternite. As this muscle is in the median line it is not repeated on each side of the animal (Pl. LXXVII. fig. 3).

The *median antero-posterior muscle* (22) of the fourth segment of the mesosoma; the *median antero-posterior muscle* (23) of the fifth segment of the mesosoma; and the *median antero-posterior muscle* (24) of the sixth segment of the mesosoma, are similar to the median antero-posterior muscle (21) of the third segment of the mesosoma.

The *lateral antero-posterior muscle* (25) of the first segment of the mesosoma is attached anteriorly to the plastron, and posteriorly to the suprapectinal chondrite (Pl. LXXX. fig. 14).

The *lateral antero-posterior muscle* (26) of the second segment of the mesosoma is attached anteriorly to the suprapectinal chondrite, and posteriorly to the sternite of the third segment (Pl. LXXVII. fig. 3, and Pl. LXXIX. fig. 14).

The *lateral antero-posterior muscle* (27) of the third segment of the mesosoma is a similar muscle to (26), but is attached anteriorly to the sternite of its own segment, and posteriorly to the sternite of the following segment. This muscle is lateral to the median antero-posterior muscle (21) of the first segment of the mesosoma.

The *lateral antero-posterior muscle* (28) of the fourth segment of the mesosoma, and the *lateral antero-posterior muscle* (29) of the fifth segment of the mesosoma are similar to the lateral antero-posterior muscle (27) of the third segment of the mesosoma, and are attached anteriorly to the sternite of the segment to which they belong and posteriorly to the sternite of the following segment.

The *lateral antero-posterior muscle* (30) of the sixth segment of the mesosoma is similar to the lateral antero-posterior muscle (27) of the third segment of the mesosoma, except that it is attached anteriorly to the sternite of the sixth segment, and posteriorly to the arthrodial membrane posterior to the segment.

The *arthrodio-sternal obliquus muscle* (31) of the third segment of the mesosoma is a small muscle superficial to the lateral antero-posterior muscle (27), attached posteriorly to the arthrodial membrane posterior to the segment. It runs obliquely forward towards the median line, and is attached anteriorly to the sternite.

The *arthrodio-sternal obliquus muscle* (32) of the fourth segment of the mesosoma,

the *arthrodio-sternal obliquus muscle* (33) of the fifth segment of the mesosoma, and the *arthrodio-sternal obliquus muscle* (34) of the sixth segment of the mesosoma are similar in form and position to the *arthrodio-sternal obliquus muscle* (31) of the third segment of the mesosoma.

The *post-stigmatic muscle* (35) of the third segment of the mesosoma is a small muscle attached anteriorly to the posterior edge of the stigmata of the lung-sac, and posteriorly to the arthrodial membrane posterior to the segment (for the *post-stigmatic muscles* see Pl. LXXVIII. figs. 8 & 9).

The *post-stigmatic muscle* (36) of the fourth segment of the mesosoma, the *post-stigmatic muscle* (37) of the fifth segment of the mesosoma, and the *post-stigmatic muscle* (38) of the sixth segment of the mesosoma are similar muscles to the *post-stigmatic muscle* (35) of the third segment of the mesosoma.

c. *Metasoma.*

Dorsal.—The *arthrodio-tergal rectus muscle* (39) of the first segment of the metasoma is a small muscle attached posteriorly to the arthrodial membrane posterior to the segment; running forwards by the side of the pericardium it is attached anteriorly to the tergite.

The *arthrodio-tergal rectus muscle* (40) of the second segment of the metasoma is attached posteriorly to the arthrodial membrane posterior to the segment; running forwards by the side of the median line it spreads out anteriorly, and is attached to the tergite.

The *arthrodio-tergal rectus muscle* (41) of the third segment of the metasoma and the *arthrodio-tergal rectus muscle* (42) of the fourth segment of the metasoma are exactly similar to the *arthrodio-tergal muscle* (40) of the second segment of the metasoma.

The *arthrodio-tergal rectus muscle* (43) of the fifth segment of the metasoma is a narrow muscle attached posteriorly to the arthrodial membrane posterior to the segment which runs forward by the median line, and is attached to the tergite.

The *arthrodio-tergal rectus muscle* (44) of the sixth segment of the metasoma is narrow and long: it is attached to the arthrodial membrane posterior to the segment, and runs forward by the median line, being attached anteriorly to the tergite.

The *arthrodio-tergal obliquus muscle* (45) of the first segment of the metasoma is a small muscle attached posteriorly to the arthrodial membrane posterior to the segment. It runs obliquely forward, towards the median line, and is attached anteriorly to the tergite. This muscle is similar to the *arthrodio tergal obliquus muscles* (9–14) in the segments of the mesosoma.

The *arthrodio-tergal obliquus muscle* (46) of the second segment of the metasoma, the *arthrodio-tergal obliquus muscle* (47) of the third segment of the metasoma, and the *arthrodio-tergal obliquus muscle* (48) of the fourth segment of the metasoma are

similar to the arthrodio-tergal obliquus muscle (45) of the first segment of the metasoma. There are no corresponding muscles in the fifth and sixth segments of the metasoma.

The *superficial dorso-ventral muscle* (49) of the first segment of the metasoma is attached to the arthrodial membrane posterior to the segment on the ventral surface, and bends round superficially to the tergite to which it is attached. This muscle is unlike any other, in that it starts on the ventral surface and bends round superficially to the tergite.

Ventral.—The *median antero-posterior muscle* (50) of the first segment of the metasoma is attached to the arthrodial membrane, anterior and posterior to the segment. It is similar to the median antero-posterior muscles in the mesosoma.

The *arthrodio-sternal rectus muscle* (50 A) of the first segment of the metasoma is attached posteriorly to the arthrodial membrane posterior to the segment; running forward it is attached anteriorly to the sternite.

The *lateral antero-posterior muscle* (51) of the first segment of the metasoma is attached to the arthrodial membrane anterior and posterior to the segment. This muscle is similar to the lateral antero-posterior muscles (25–30) of the mesosoma; but there is no further continuation of it in the following segments.

The *median antero-posterior muscle* (52) of the second segment of the metasoma is a large muscle lying in the median line, and therefore not repeated on each side of the animal. It is attached to the arthrodial membrane anterior and posterior to the segment.

The *median antero-posterior muscle* (53) of the third segment of the metasoma, the *median antero-posterior muscle* (54) of the fourth segment of the metasoma, and the *median antero-posterior muscle* (55) of the fifth segment of the metasoma are similar to the median antero-posterior muscle (52) of the second segment of the metasoma. There is no corresponding muscle in the sixth segment.

The *lateral arthrodio-sternal muscle* (56) of the second segment of the metasoma is attached to the arthrodial membrane posterior to the segment; it runs forward and is attached to the sternite, and lies lateral to the median antero-posterior muscle (52).

The *lateral arthrodio-sternal muscle* (57) of the third segment of the metasoma and the *lateral arthrodio-sternal muscle* (58) of the fourth segment of the metasoma are similar to the lateral arthrodio-sternal muscle (56) of the second segment of the metasoma.

The *lateral arthrodio-sternal muscle* (59) of the fifth segment of the metasoma is a large muscle attached to the arthrodial membrane posterior to the segment. Some of the fibres run to the dorsal surface, and are attached to the tergal portion of the sclerite, whilst the others run forward and are attached to the sternal portion.

The *lateral arthrodio-sternal muscle* (60) of the sixth segment of the metasoma is a large muscle, some of the fibres of which run dorsally and are attached to the tergal portion of the sclerite, whilst the others run ventrally and are attached to the sternite.

They are united in a common attachment on the arthrodial membrane posterior to the segment.

There are no muscles attached to the chitinous investment of the postanal spine or sting, though both 44 and 60 are attached to the arthrodial membrane connecting this body with the sixth metasomatic segment.

II. *Dorso-Ventral Muscles.*

The dorso-ventral muscles of the Scorpion lie near the longitudinal median line; they are attached dorsally and ventrally to sclerites. Certain other muscles may be classed amongst the dorso-ventral muscles, which start from the tergites near the longitudinal median line and run ventrally, but before reaching the ventral surface have been intercepted by, and are attached to, the entochondrites. For the dorso-ventral muscles see Pl. LXXVII. figs. 1, 4, 5, and Pl. LXXVIII. fig. 6.

a. *Prosoma.*

The *dorso-chelicero-sternal muscle* (61) is the most anterior of the dorso-ventral muscles. It is very small, and is attached to the carapace near the median line anterior to the central eyes; it runs forward ventrally, and is attached to the arthrodial membrane between the chelicerae.

The *median dorso-preoral entosclerite muscle* (62) is a large muscle, between which and its fellow of the opposite side are situated the eyes. It is attached dorsally to the carapace, and ventrally to the preoral entosclerite (besides the figures above cited, see Pl. LXXIX. fig. 12).

The *anterior dorso-plastron muscle* (63) is attached dorsally to the carapace in the median line, being joined to its fellow of the opposite side; they separate and are attached ventrally to the plastron. Through the arch thus formed pass the alimentary canal and the dorsal vessel (see Pl. LXXX. fig. 13).

The *median dorso-plastron muscle* (64) is attached dorsally to the posterior portion of the carapace. It runs forward on the anterior surface of the posterior flap of the plastron to the body of the plastron, to which it is attached (Pl. LXXX. fig. 13).

b. *Mesosoma.*

The *posterior dorso-plastron muscle* (65) is attached to the tergite of the first segment of the mesosoma by the side of the pericardium. It runs forward, and at first lies closely on the posterior surface of the posterior flap of the plastron; it soon penetrates the flap, and continues its course on the anterior surface until it reaches the body of the plastron, to which it is attached.

The *dorso-suprapectinal-chondrite muscle* (66) is attached to the second tergite of the mesosoma by the side of the pericardium. It runs forward to the suprapectinal chondrite, to which it is attached (see Pl. LXXIX. fig. 14).

The *dorso-ventral muscle* (67) of the third segment of the mesosoma is attached to the tergite of the third segment by the side of the pericardium. On passing to the sternite of the third segment to which it is attached, it runs through the lateral antero-posterior muscle (27) of the ventral longitudinal muscles, having a portion of the latter muscle between itself and the lung-sac (see Pl. LXXVIII. figs. 8, 9).

The *dorso-ventral muscle* (68) of the fourth segment of the mesosoma, the *dorso-ventral muscle* (69) of the fifth segment of the mesosoma, and the *dorso-ventral muscle* (70) of the sixth segment of the mesosoma are similar in position and character to the dorso-ventral muscle (67) of the third segment of the mesosoma, being attached to the tergites and sternites of the segments to which they belong.

c. *Metasoma.*

The *dorso-ventral muscle* (71) of the first segment of the metasoma is similar to the dorso-ventral muscles (67-70) of the mesosoma. There are no dorso-ventral muscles in the following segments of the metasoma.

III. *Muscles attached to the Plastron or First Entochondrite.* (Plate LXXVII. fig. 1, and Plate LXXX. figs. 13, 14.)

The plastron forms the base of attachment for many muscles, the larger number of which are distributed to the appendages. In order to distinguish the muscles belonging to the different appendages, I have called them "first," "second," &c., in reference to the appendages to which they belong. Other muscles are distributed from the plastron to the dorsal and ventral epidermal sclerites, to the epimeron, and to the suprapectinal chondrite.

The muscles between the plastron and the dorsal surface have been mentioned above among the dorso-ventral muscles under the names of—

The *anterior dorso-plastron* (63);

The *median dorso-plastron* (64); and

The *posterior dorso-plastron* (65) muscles.

The *anterior second coxo-plastron muscle* (72) is attached posteriorly to the anterior process of the plastron; running forward, it is attached anteriorly to the second coxal sclerite.

The *third deutomerite-plastron muscle* (73) is attached to the anterior process of the plastron. It runs into the third appendage, and is attached to the interior edge of the deutomerite sclerite.

The *third postcoxal entosclerite-plastron muscle* (74) is attached to the anterior process of the plastron. It spreads out on the posterior surface of the third coxal entosclerite, to which it is attached.

The *median second coxo-plastron muscle* (75) is attached posteriorly to the body of

the plastron on the anterior side of the base of the anterior process. It runs forward, and is attached anteriorly to the second coxal sclerite.

The *posterior second coxo-plastron muscle* (76) is attached posteriorly to the body of the plastron posterior to the attachment of the muscle 75. It runs forward, and is attached to the second coxal sclerite.

The *fourth deutomerite-plastron muscle* (77) is attached to the lateral portion of the body of the plastron posterior to the anterior process. It runs into the fourth appendage, and is attached to the interior margin of the deutomerite sclerite.

The *fourth postcoxal entosclerite plastron muscle* (78) is attached to the median lateral process of the plastron. It spreads out on the posterior surface of the fourth coxal entosclerite, to which it is attached.

The *anterior epimero-plastron muscle* (79) is attached to the lateral portion of the body of the plastron posterior to the median lateral process, and to the arthrodial membrane between the fourth and fifth appendages behind the posterior fourth coxal entosclerite.

The *fifth deutomerite-plastron muscle* (80) is attached to the posterior process of the plastron, running into the fifth appendage. It is attached to the interior margin of the deutomerite sclerite.

The *median epimero-plastron muscle* (81) is attached to the posterior process of the plastron and to the lateral portion of the arthrodial membrane between the fifth and sixth appendages.

The *sixth deutomerite-plastron muscle* (82) is attached to the posterior process of the plastron. It runs into the sixth appendage, and is attached to the interior margin of the deutomerite sclerite.

The *posterior epimero-plastron muscle* (83) is attached to the posterior part of the body of the plastron. It runs laterally for a short distance on the anterior surface of the posterior flap of the plastron, but soon penetrates the flap, and continues on the posterior surface (see Pl. LXXX. figs. 13 & 14). It is attached to the arthrodial membrane posterior to the sixth coxal sclerite.

The *sterno-subneural plastron muscle* (84) is a small muscle attached to the anterior subneural process of the plastron, and, ventrally, to the small postoral entosclerite.

The *operculo-plastron muscle* (85) is attached to the posterior part of the subneural portion of the plastron and to the seventh appendage or genital operculum.

The *plastron-suprapectinal-chondrite muscle* (86) is a small muscle attached anteriorly to the posterior part of the subneural portion of the plastron, and posteriorly to the anterior face of the suprapectinal chondrite.

The *lateral antero-posterior muscle* (25) has already been mentioned with the ventral longitudinal muscles. It starts from the posterior part of the subneural portion of the plastron, and is attached posteriorly to the suprapectinal chondrite.

The *sixth coxo-plastron muscle* (86 a) is attached to the lateral portion of the plastron

ventral to the lateral median process, and to the arthrodial membrane between the metasternite and the coxal joint of the sixth appendage.

IV. *Muscles attached to the Suprapectinal Chondrite.*

The *lateral antero-posterior muscle* (25) of the first segment of the mesosoma has already been mentioned as being attached posteriorly to the suprapectinal chondrite and anteriorly to the plastron.

The *lateral antero-posterior muscle* (26) of the second segment of the mesosoma is attached anteriorly to the suprapectinal chondrite.

The *dorso-suprapectinal-chondrite muscle* (66) of the dorso-ventral series of muscles is attached to the superior surface of the suprapectinal chondrite, as has been mentioned above in speaking of the dorso-ventral muscles.

The *plastron-suprapectinal-chondrite muscle* (86) has been mentioned with the muscles attached to the plastron as being attached anteriorly to the plastron and posteriorly to the suprapectinal chondrite.

The *epimero-suprapectinal-chondrite muscle* (87) is a small muscle attached to the most lateral portion of the suprapectinal chondrite. It is also attached to the epimeron lateral to the pecten.

The *posterior pectino-suprapectinal-chondrite muscle* (88) is a small but broad muscle which runs from the inferior portion of the suprapectinal chondrite to the posterior margin of the pectine.

The *sterno-suprapectinal-chondrite muscle* (89) starts from the suprapectinal chondrite, and runs to the sclerite between the pair of pectines.

The *anterior pectino-suprapectinal-chondrite muscle* (90) is a small but broad muscle which runs from the inferior surface of the suprapectinal chondrite to the anterior margin of the pecten.

The *interior pectino-suprapectinal-chondrite muscle* (91) is a small muscle attached to the median part of the suprapectinal chondrite, which runs down to the interior margin of the pecten.

The *exterior pectino-suprapectinal-chondrite muscle* (92) is attached to the suprapectinal chondrite, and runs down to the exterior margin of the pecten.

V. *Muscles attached to the Preoral Entosclerite.* (See Plate LXXIX. figs. 11, 12, and 16.)

Muscles are distributed from the preoral entosclerite to the dorsal surface, the coxal entosclerite of the first appendage, and to the pharynx. There are four muscles to the dorsal surface, of which one has a median attachment, the other three have lateral attachments.

The *median dorso-preoral entosclerite muscle* (62) is attached to the anterior part of

the preoral entosclerite, and runs straight up, being attached to the carapace near the median line (one on each side). It has been mentioned before amongst the dorso-ventral muscles.

The *anterior latero-dorsal preoral entosclerite muscle* (93) is attached to the anterior part of the preoral entosclerite. It runs underneath the coxal entosclerite of the first appendage, and is attached to the lateral part of the carapace.

The *median latero-dorsal preoral entosclerite muscle* (94) is attached to the posterior process of the preoral entosclerite, and runs laterally to the carapace, to which it is attached.

The *posterior latero-dorsal preoral entosclerite muscle* (95) is attached to the posterior part of the posterior process of the preoral entosclerite, and runs laterally to the carapace, to which it is attached.

The *anterior first-coxal-entosclerite preoral-entosclerite muscle* (96) is a broad muscle attached to the interior surface of the posterior process of the preoral entosclerite and to the interior surface of the first coxal entosclerite.

The *posterior first-coxal-entosclerite preoral-entosclerite muscle* (97) is a small muscle attached to the posterior end of the posterior process of the preoral entosclerite and to the posterior portion of the first coxal entosclerite.

The *anterior preoral entosclerite pharyngeal muscle* (98) (Pl. LXXIX. fig. 12) is a small muscle attached to the interior surface of the anterior portion of the preoral entosclerite, and runs down to the pharynx, to which it is attached on its superior surface.

The *posterior preoral entosclerite pharyngeal muscle* (99) (Pl. LXXIX. fig. 11) is a larger muscle, attached to the interior surface of the preoral entosclerite. It runs horizontally towards the similar muscle of the other side, and is attached to the lateral walls of the pharynx.

VI. *Muscles to the Appendages.*

Prosoma.—The muscles belonging to the appendages of the prosoma are of two kinds, intrinsic and extrinsic.

Intrinsic Muscles.—Of the intrinsic muscles, I shall only speak of those which run inwards from the appendages, and are attached internally to the coxal entosclerite or to the interior margin of the coxal sclerite. In speaking of the interior margin of the coxal and deutomerite sclerites I refer to that margin nearest to the body of the animal.

The *exterior first-coxal entosclerite-deutomerite muscle* (100) is a broad muscle attached posteriorly to the exterior margin of the coxal entosclerite and anteriorly to the interior margin of the deutomerite sclerite of the first appendage.

The *interior first-coxal entosclerite-deutomerite muscle* (101) is a narrow muscle

attached to the posterior portion of the first coxal entosclerite and to the interior margin of the deutomerite sclerite of the first appendage.

The *third-coxal entosclerite-deutomerite muscle* (102) is attached to the third coxal entosclerite and to the interior margin of the deutomerite sclerite of the third appendage.

The *fourth-coxal entosclerite-deutomerite muscle* (103) is attached to the fourth coxal entosclerite and to the interior margin of the deutomerite sclerite of the fourth appendage.

The *fifth coxo-deutomerite muscle* (104) is attached to the fifth coxal sclerite and to the interior margin of the deutomerite sclerite of the fifth appendage.

The *sixth coxo-deutomerite muscle* (105) is attached to the sixth coxal sclerite and to the interior margin of the deutomerite sixth sclerite of the sixth appendage.

Extrinsic Muscles.—Most of the extrinsic muscles of the appendages are attached to the carapace; when this is removed a compact mass of muscles is exposed, which is shown in Pl. LXXVIII. fig. 6. The under-surface of the carapace, with the attachments of the muscles, is represented in Pl. LXXVIII. fig. 7, and the attachments of the muscles to the appendages are shown in Pl. LXXIX. fig. 16. There are three series of extrinsic muscles to the appendages of the prosoma—those running to the deutomerite sclerites, the coxal sclerites, and the coxal entosclerites.

Deutomerite Muscles.—There is one deutomerite muscle to each of the appendages of the prosoma, with the exception of the first, to which there are two. These muscles are attached extrinsically to the carapace (those running to the first and second appendages) and to the plastron (those to the third, fourth, fifth, and sixth appendages).

The deutomerite muscles (73, 77, 80, 82) from the plastron have already been described under the muscles attached to the plastron; it remains to mention those from the carapace to the first and second appendages.

The *superior first dorso-deutomerite muscle* (106) is a narrow muscle attached to the carapace near the median line posterior to the eyes; running forward, it is attached to the superior portion of the interior margin of the deutomerite sclerite of the first appendage.

The *inferior first dorso-deutomerite muscle* (107) is a larger muscle, attached to the carapace more laterally. It runs forward and is attached to the inferior portion of the interior margin of the deutomerite sclerite of the first appendage.

The *second dorso-deutomerite muscle* (108) is a thick muscle attached to the carapace towards its posterior portion. It runs forward to the exterior portion of the interior margin of the deutomerite sclerite of the second appendage, to which it is attached.

Coxal Muscles.—The coxal muscles are attached extrinsically to the carapace, with the exception of three which run to the coxal sclerite of the second appendage from the plastron and have been mentioned above under the muscles attached to the plastron (72, 75, 76).

The *exterior first dorso-coxal muscle* (109) is attached to the carapace near the

median line. It runs laterally to the exterior portion of the interior margin of the coxal sclerite of the first appendage.

The *interior first dorso-coxal muscle* (110) is a large muscle, the larger part of which is attached posteriorly, the smaller part more laterally, to the carapace; these are united in a common origin at the interior portion of the interior margin of the coxal sclerite of the first appendage.

The *superior first dorso-coxal muscle* (111) is attached posteriorly to the carapace. It is a narrow muscle, running underneath the larger part of the last-mentioned muscle, and is attached anteriorly to the superior portion of the coxal sclerite of the first appendage.

The *anterior second dorso-coxal muscle* (112) is a thick muscle attached posteriorly to the carapace, and running forward to the antero-lateral portion of the interior margin of the second coxal sclerite.

The *posterior second dorso-coxal muscle* (113) is attached to the carapace towards its lateral portion and to the postero-lateral portion of the interior margin of the second coxal sclerite.

The *third dorso-coxal muscle* (114) is attached to the lateral portion of the carapace and to the antero-lateral portion of the interior margin of the third coxal sclerite.

The *fourth dorso-coxal muscle* (115) is attached to the lateral portion of the carapace and to the antero-lateral portion of the interior margin of the fourth coxal sclerite.

The *anterior fifth dorso-coxal muscle* (116) is attached to the carapace near the median line, at its posterior portion, and to the antero-lateral portion of the interior margin of the fifth coxal sclerite.

The *posterior fifth dorso-coxal muscle* (117) is attached to the lateral portion of the carapace and to the postero-lateral portion of the interior margin of the fifth coxal sclerite.

The *anterior sixth dorso-coxal muscle* (118) is attached to the posterior portion of the carapace near the median line and to the antero-lateral portion of the interior margin of the sixth coxal sclerite.

The *posterior sixth dorso-coxal muscle* (119) is attached to the lateral portion of the carapace and to the postero-lateral portion of the interior margin of the sixth coxal sclerite.

Coxal Entosclerite Muscles.—The extrinsic muscles of the coxal entosclerites are attached to the plastron and to the carapace. Those running from the plastron are attached to the posterior surfaces of the third and fourth posterior coxal entosclerites, and have been mentioned under the muscles attached to the plastron (74, 78).

There are four muscles from the carapace to the coxal entosclerites, two of which are attached to that of the first appendage, and one to each of the posterior coxal entosclerites of the third and fourth appendages.

The *lateral first dorso-coxal entosclerite muscle* (120) is attached to the lateral portion

of the carapace. It runs inwards, and is attached to the posterior part of the first coxal entosclerite.

The *posterior first dorso-coxal entosclerite muscle* (121) is attached posteriorly to the carapace. Running forwards, it is attached to the exterior edge of the first coxal entosclerite.

The *third dorso-coxal entosclerite muscle* (122) is a thin broad muscle attached to the carapace towards its lateral portion and to the posterior margin of the posterior third coxal entosclerite.

The *fourth dorso-coxal entosclerite muscle* (123) is attached to the carapace and to the posterior margin of the posterior fourth coxal entosclerite.

Mesosoma.—To the first appendage of the mesosoma, or genital operculum, there is only one muscle, which is attached to the plastron, and has been already mentioned with the muscles which are attached to the plastron as the seventh plastron muscle (85). (See Pl. LXXX. figs. 13, 14.)

To the second appendage, or pectine, there are six muscles, four of which are attached to the suprapectinal chondrite, and have been already mentioned with the muscles attached to the suprapectinal chondrite as the posterior (88), anterior (90), interior (91), and exterior (92) pectino-suprapectinal-chondrite muscles (see Pl. LXXIX. fig. 14).

The *epimero-pectinal muscle* (124) is attached to the epimeron by the postero-lateral portion of the interior margin of the sixth coxal sclerite. It runs into the pectine (fig. 8).

The *sterno-pectinal muscle* (125) is attached to the sternal sclerite, on which the pectines are carried near the median line; it runs laterally, and is attached to the interior portion of the opening of the pectine (Pl. LXXIX. fig. 14).

No muscles are attached directly to the lung-books, although there are two series of muscles by which they are influenced. Amongst the ventral longitudinal muscles will be seen the post-stigmatic muscles (35, 36, 37, & 38) of the third, fourth, fifth, and sixth segments of the mesosoma; these are attached to the posterior edge of the stigmata and to the arthrodial membrane posterior to the segment in which they occur.

The muscles of the other series run ventralwards from the pericardium, and spread out on the surface of the blood-holding lung-sac in those segments in which the lung-books occur. Of this series I shall speak later under the heading of "Muscles to the Pericardium."

VII. *Muscles to the Epimeron.* (Plate LXXVII. fig. 1, and Plate LXXVIII. fig. 6)

Muscles are distributed to the epimeron from the carapace, the plastron, the second entochondrite, and the pectines. All of these have been mentioned above, with the exception of those from the carapace.

The muscles 79, 81, & 83 run between the epimeron and the plastron, the muscle 87 between the epimeron and the second entochondrite, and the muscle 124 between the epimeron and the pectine.

The *anterior dorso-epimeron muscle* (126) is attached to the lateral portion of the carapace and to the epimeron lateral to the interior margin of the second coxal sclerite.

The *median dorso-epimeron muscle* (127) is attached to the lateral portion of the carapace and to the epimeron lateral to the interior margin of the third coxal sclerite.

The *posterior dorso-epimeron muscle* (128) is attached to the lateral portion of the carapace, and to the epimeron lateral to the interior margin of the fourth coxal sclerite.

VIII. *Muscles to the Pharynx.* (See Plate LXXIX. figs. 11, 12.)

The pharynx of the Scorpion is a large dilatation of the alimentary canal closely following the aperture of the mouth. This aperture is so minute that the animal lives entirely on the juices of its prey, and on the hard parts finely pulverized by the action of the chelicerae: these juices are drawn in at the oral aperture by the expansion and contraction of the pharynx. On contracting the muscles form within the pharynx a partial vacuum; and as the aperture of the œsophagus on leaving the pharynx is smaller than that of the mouth, the vacuum is more readily filled from the latter. The muscles attached to the pharynx are of two kinds, the extrinsic, which dilate, and the intrinsic, which contract it. It is thus rendered a powerful suctorial organ. In transverse section it is shown to be very narrow, the lateral walls almost meeting; its dorsal portion is curved downwards, and forms a lateral groove, which gives it a triradiate form.

The *dorsal intrinsic muscle* (129) consists of three small bands of muscle which are attached to the dorsal surface of the pharynx within, and to the walls on either side of the groove. This muscle is so small that it is only by means of sections that it is visible; it is, of course, not repeated on either side of the animal, as it is itself in the median line.

The *lateral intrinsic muscle* (130) runs closely by the lateral walls of the pharynx, and is attached dorsally and ventrally to its walls. This muscle cannot be seen without the aid of sections.

The *anterior preoral entosclerite pharyngeal muscle* (98) (Pl. LXXIX. fig. 12) is a small muscle attached to the ventral surface of the anterior portion of the preoral entosclerite. It runs down almost vertically into the groove on the dorsal surface of the pharynx, to the wall of which it is attached.

The *posterior preoral entosclerite pharyngeal muscle* (99) is a larger muscle attached to the interior surface of the processes of the preoral entosclerite, and runs almost horizontally to the lateral wall of the pharynx, to which it is attached.

IX. *Muscles to the Pericardium.* (See Plate LXXVII. figs. 1, 4, 5, and Plate LXXX. fig. 15.)

There is a series of muscles attached to the ventral wall of the pericardium, running ventrally and attached to the ventral portion of the investment of connective tissue which lines the body; they lie slightly anterior to the dorso-ventral muscles, mentioned before as being attached to the tergites and sternites of the mesosoma. There is one in each of the five last segments of the mesosoma, and two in the first segment of the metasoma. Dorsally they are attached nearer to the median line than the dorso-ventral muscles, which are attached to the tergites by the side of the pericardium; but before reaching the sternal surface they cross over, and their ventral attachment is exterior to that of the dorso-ventral muscles. In the four segments in which the lung-books occur they spread out ventrally, and are attached to the surface of the venous sacs, into which the introverted lamellæ of the branchial appendages (or lung-books) are sunk. These muscles are hollow, both above and below; but the middle region is solid, so that the blood does not pass from the pulmonary sinus to the pericardium through them, as might at first seem likely. They are exactly equivalent to the veno-pericardiac muscles of *Limulus* (68), the "brides transparentes" of M. Alphonse Milne-Edwards.

a. *Mesosoma.*

The *pericardio-ventral muscle* (131) of the second segment of the mesosoma is attached dorsally to the pericardium, running forward closely in front of the dorso-suprapectinal chondrite muscle (66); it is attached ventrally to the connective investment of the body exterior to the above-mentioned muscle.

The *pericardio-ventral muscle* (132) of the third segment of the mesosoma is attached dorsally to the pericardium, running down closely anterior to the dorso-ventral muscle (67); it is attached ventrally to the first lung-sac, exterior to the dorso-ventral muscle (67).

The *pericardio-ventral muscle* (133) of the fourth segment of the mesosoma; the *pericardio-ventral muscle* (134) of the fifth segment of the mesosoma; and the *pericardio-ventral muscle* (135) of the sixth segment of the mesosoma are similar to the *pericardio-ventral muscle* (132) of the third segment, and take a corresponding position in the segments to which they belong.

b. *Metasoma.*

The *anterior pericardio-ventral muscle* (136) of the first segment of the metasoma is attached dorsally to the pericardium, running closely anterior to the dorso-ventral muscle (71) of the first segment of the metasoma, and is attached ventrally to the connective investment of the body exterior to the muscle (71).

The *posterior pericardio-ventral muscle* (137) of the first segment of the metasoma is

exactly similar to the anterior pericardio-ventral muscle (136), except that it runs on the posterior instead of the anterior side of the dorso-ventral muscle (71).

The pericardium is not continued into the five subsequent segments of the metasoma, and accordingly we do not find there any muscles representing the veno-pericardiacs of the mesosoma and first metasomatic segment.

Reference to letters in Plates LXXVII., LXXVIII., LXXIX.

- I. Chelicera, first appendage.
- II. Chela, second appendage.
- III.-VI. Four ambulatory appendages.
- VII.-XII. Six segments of mesosoma.
- XIII.-XVIII. Six segments of metasoma.
- A. First coxal entosclerite.
- B. Second coxal entosclerite.
- C. Anterior third coxal entosclerite.
- D. Posterior third coxal entosclerite.
- E. Anterior fourth coxal entosclerite.
- F. Posterior fourth coxal entosclerite.
- G. Fifth coxal entosclerite.
- H. Preoral entosclerite.
- K. Postoral entosclerite.
- L. Carino-sternal entosclerite.
- N.C. Canal in plastron through which nerve-cord passes.
- V.C. Ventral portion of carapace turned under anteriorly (transparent).
- V.S. Vascular space in pericardio-ventral muscle.
- ac. Alimentary canal.
- am. Arthrodial membrane, covering the body between the chitinous plates.
- ap. Anterior process of plastron.
- arc. Arterial canal-aperture in posterior flap of plastron through which the dorsal vessel runs.
- cam. Camerostome or upper lip.
- car. Carapace.
- ce. Central eyes.
- cg. Coxal glands.
- dr. Dorsal ridge of plastron.
- dv. Dorsal vessel (anterior continuation of heart).
- gc. Gastric canal-aperture in posterior flap of plastron, through which the alimentary canal runs.
- go. Genital operculum (seventh appendage).
- le. Lateral eyes.

- ls, ls₂ ls₃ ls₄. Lung-sacs (blood-containing envelopes of the lung-books) in four last segments of mesosoma.
- Imp. Lateral median process of plastron.
- m. Mouth.
- m¹. Aperture in flap of plastron through which muscle 83 passes.
- m². Aperture in flap of plastron through which muscle 65 passes.
- md. Divisions between muscles.
- met. Thoracic metasternite.
- mf. Muscular fibres.
- nc. Nerve-cord.
- ng. Nerve-ganglion.
- p. Pericardium.
- pa. Postanal spine.
- pec. Pecten (eighth appendage).
- pf. Posterior flap of plastron.
- ph. Pharynx.
- pl. Plastron.
- pp. Posterior process of plastron.
- snp. Subneural process of plastron.
- sps. Suprapectinal chondrite.
- sts. Sternal sclerite on which pectines are carried in second segment of mesosoma.
- æ. Cut edge of carapace.
- γ. Cut edge of tergites.
- 1. Antero-posterior muscle (prosoma).
- 2. Arthrodio-tergal obliquus muscle (prosoma).
- 3-8. Antero-posterior muscles (mesosoma).
- 9-14. Arthrodio-tergal obliquus muscles (mesosoma).
- 15-20. Latero-dorsal muscles (mesosoma).
- 21-24. Median antero-posterior muscles (mesosoma).
- 25-30. Lateral antero-posterior muscles (mesosoma).
- 31-34. Arthrodio-sternal obliquus muscles (mesosoma).
- 35-38. Post-stigmatic muscles (mesosoma).

- 39-44. Arthrodio-tergal rectus muscles (metasoma).
- 45-48. Arthrodio-tergal obliquus muscles (metasoma).
49. Superficial dorso-ventral muscle (metasoma).
50. Median antero-posterior muscle (metasoma).
- 50 A. Arthrodio-sternal rectus muscle (metasoma).
51. Lateral antero-posterior muscle (metasoma).
- 52-55. Median antero-posterior muscles (metasoma).
- 56-60. Lateral arthrodio-sternal muscles (metasoma).
61. Dorso-chelicero-sternal muscle.
62. Median dorso-preoral entosclerite muscle.
63. Anterior dorso-plastron muscle.
64. Median dorso-plastron muscle.
65. Posterior dorso-plastron muscle.
66. Dorso-suprapectinal chondrite muscle.
- 67-70. Dorso-ventral muscles (mesosoma).
71. Dorso-ventral muscle (metasoma).
72. Anterior second coxo-plastron muscle.
73. Third deutomerite-plastron muscle.
74. Third postcoaxal entosclerite-plastron muscle.
75. Median second coxo-plastron muscle.
76. Posterior second coxo-plastron muscle.
77. Fourth deutomerite-plastron muscle.
78. Fourth postcoaxal entosclerite-plastron muscle.
79. Anterior epimero-plastron muscle.
80. Fifth deutomerite-plastron muscle.
81. Median epimero-plastron muscle.
82. Sixth deutomerite-plastron muscle.
83. Posterior epimero-plastron muscle.
84. Sterno-subncural plastron muscle.
85. Opereulo-plastron muscle.
86. Plastron suprapectinal chondrite muscle.
- 86 A. Sixth coxo-plastron muscle.
87. Epimero-suprapectinal chondrite muscle.
88. Posterior pectine suprapectinal chondrite muscle.
89. Sterno-suprapectinal chondrite muscle.
90. Anterior pectine suprapectinal chondrite muscle.
91. Interior pectine suprapectinal chondrite muscle.
92. Exterior pectine suprapectinal chondrite muscle.
93. Anterior latero - dorsal preoral entosclerite muscle.
94. Median latero-dorsal preoral entosclerite muscle.
95. Posterior latero-dorsal preoral entosclerite muscle.
96. Anterior first-coxal entosclerite preoral entosclerite muscle.
97. Posterior first-coxal entosclerite preoral entosclerite muscle.
98. Anterior preoral entosclerite-pharyngeal muscle.
99. Posterior preoral entosclerite-pharyngeal muscle.
100. Exterior first-coxal entosclerite-deutomerite muscle.
101. Interior first-coxal entosclerite-deutomerite muscle.
102. Third-coxal entosclerite-deutomerite muscle.
103. Fourth-coxal entosclerite-deutomerite muscle.
104. Fifth coxo-deutomerite muscle.
105. Sixth coxo-deutomerite muscle.
106. Superior first dorso-deutomerite muscle.
107. Inferior first dorso-deutomerite muscle.
108. Second dorso-deutomerite muscle.
109. Exterior first dorso-coxal muscle.
110. Interior first dorso-coxal muscle.
111. Superior first dorso-coxal muscle.
112. Anterior second dorso-coxal muscle.
113. Posterior second dorso-coxal muscle.
114. Third dorso-coxal muscle.
115. Fourth dorso-coxal muscle.
116. Anterior fifth dorso-coxal muscle.
117. Posterior fifth dorso-coxal muscle.
118. Anterior sixth dorso-coxal muscle.
119. Posterior sixth dorso-coxal muscle.
120. Lateral first dorso-coxal entosclerite muscle.
121. Posterior first dorso-coxal entosclerite muscle.
122. Third dorso-coxal entosclerite muscle.
123. Fourth dorso-coxal entosclerite muscle.
124. Epimero-pectine muscle.
125. Sterno-pectine muscle.
126. Anterior dorso-epimeron muscle.
127. Median dorso-epimeron muscle.
128. Posterior dorso-epimeron muscle.
129. Dorsal intrinsic muscle of pharynx.
130. Lateral intrinsic muscle of pharynx.
- 131-137. Pericardio-ventral (veno-pericardiac) muscles.

DESCRIPTION OF PLATES LXXVII. TO LXXIX.

PLATE LXXVII.

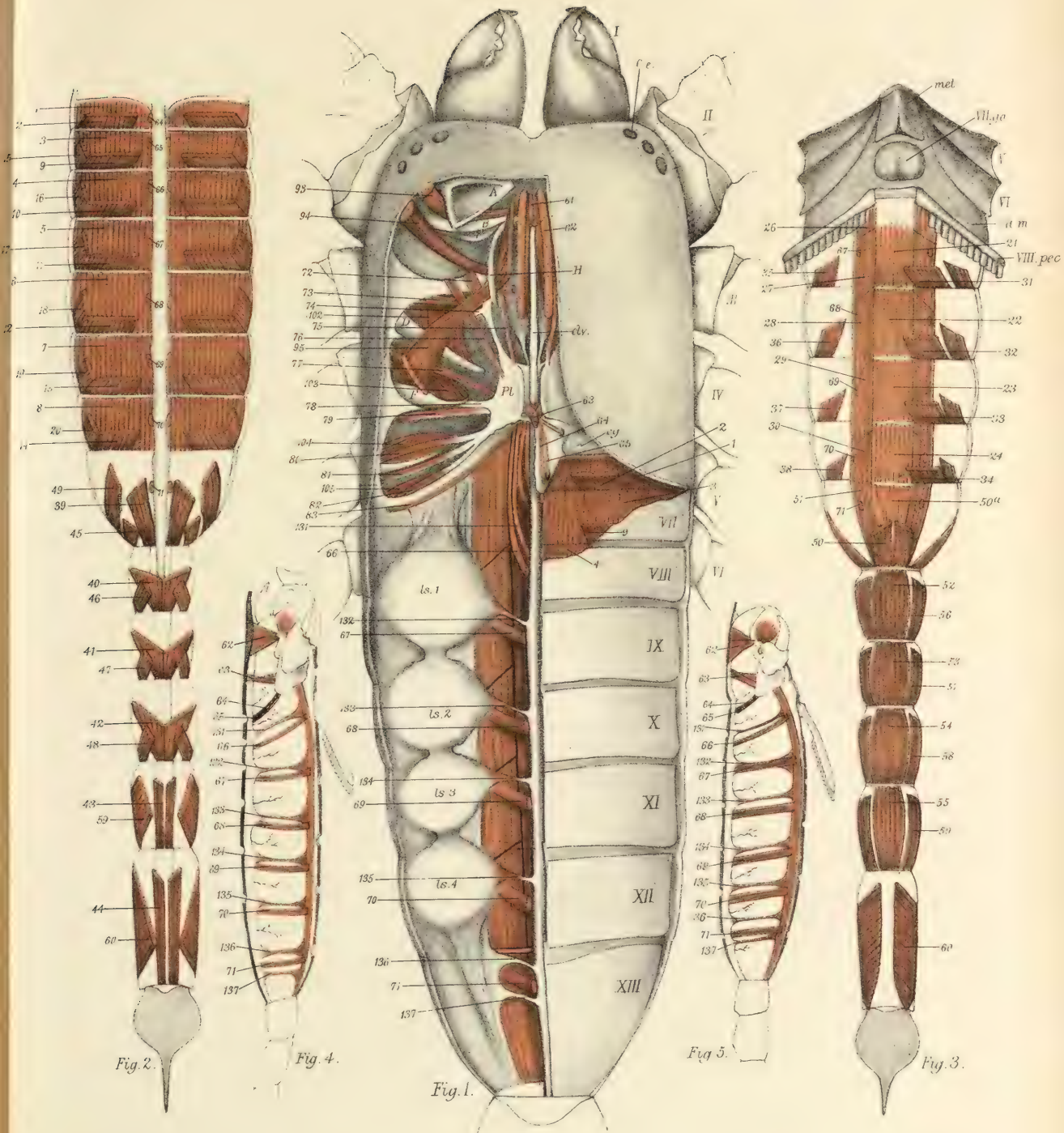
- Fig. 1. Prosoma and metasoma of *Scorpio (Buthus)*. Dorsal aspect. The tergum of the left side has been cut away and the viscera removed in order to expose the dorso-ventral muscles. The superficial muscles of the prosoma have also been removed. Besides the muscles there are seen the plastron (*Pl*), the pericardium, and the lung-sacs (*ls*).
- Fig. 2. Dorsal aspect of the mesosoma and metasoma of *Scorpio (Buthus)*. The tergites have been removed in order to show the dorsal longitudinal muscles.
- Fig. 3. Ventral aspect of the mesosoma and metasoma of *Scorpio (Buthus)*. The sternites have been removed to show the ventral longitudinal muscles; on the left the arthrodio-sternal muscles (31-34) have been removed.
- Fig. 4. Diagrammatic view of a lateral dissection of the prosoma and mesosoma of *Scorpio (Buthus)*.
- Fig. 5. Ditto of the prosoma and mesosoma of *Scorpio (Androctonus)*.

PLATE LXXVIII.

- Fig. 6. Dorsal aspect of the prosoma of *Scorpio (Buthus)*. The carapace has been removed in order to expose the muscles. On the left side the more superficial muscles are removed.
- Fig. 7. Under-surface of the carapace, showing the attachments of the muscles.
- Fig. 8. Mesosoma of *Scorpio (Buthus)*. Dorsal aspect. The tergites and viscera have been removed in order to show the muscles, lung-sacs, and nerves.
- Fig. 9. Mesosoma of *Scorpio (Androctonus)*. Dorsal aspect. Tergites and viscera removed.

PLATE LXXIX.

- Fig. 10. Transverse section of a pericardio-ventral muscle from the mesosoma of *Scorpio (Buthus)*, showing vascular space (*vs*) cut across.
- Fig. 11. Transverse section across the prosoma of *Scorpio (Italicus)*, showing the muscles attached to the pharynx.
- Fig. 12. Transverse section of the same pharynx anterior to fig. 11.
- Fig. 13. Carapace of *Scorpio (Buthus)*. Ventral aspect.
- Fig. 14. Transverse section of the segment bearing the pectines, showing the supra-pectinal chondrite (*spe*) with muscles attached.
- Fig. 15. View of a longitudinally divided prosoma of *Scorpio (Buthus)*. All the viscera removed, and only the hard skeletal parts left (compare with woodcut, fig. 1).
- Fig. 16. View of the inner sternal surface of the prosoma of *Scorpio (Buthus)*. All the viscera removed, only the hard skeletal parts left.



E. J. Beck del. C. Berjeau lith.

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ANATOMY OF SCORPIO.

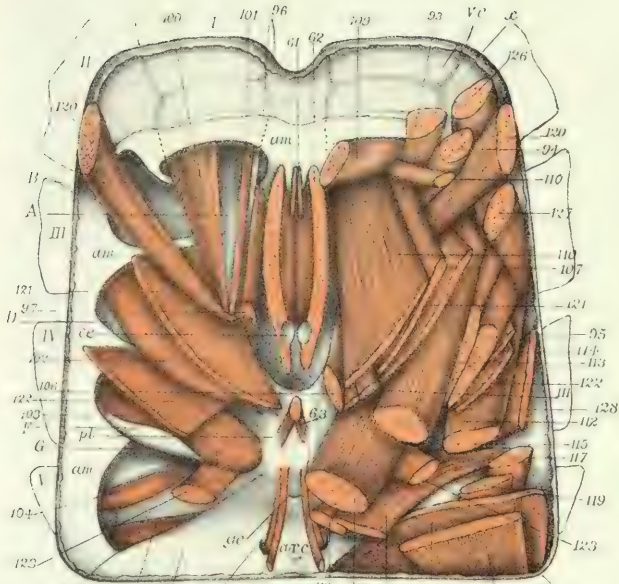


Fig. 6.

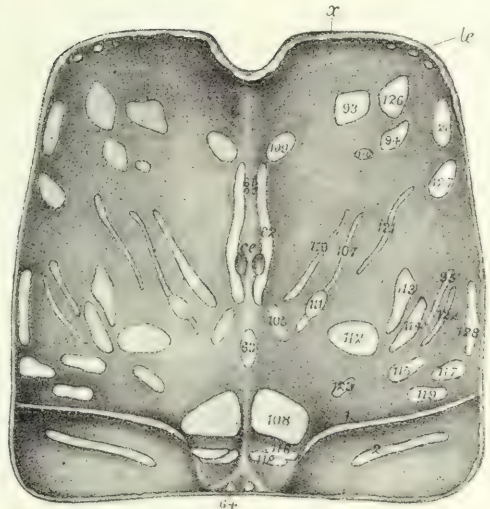
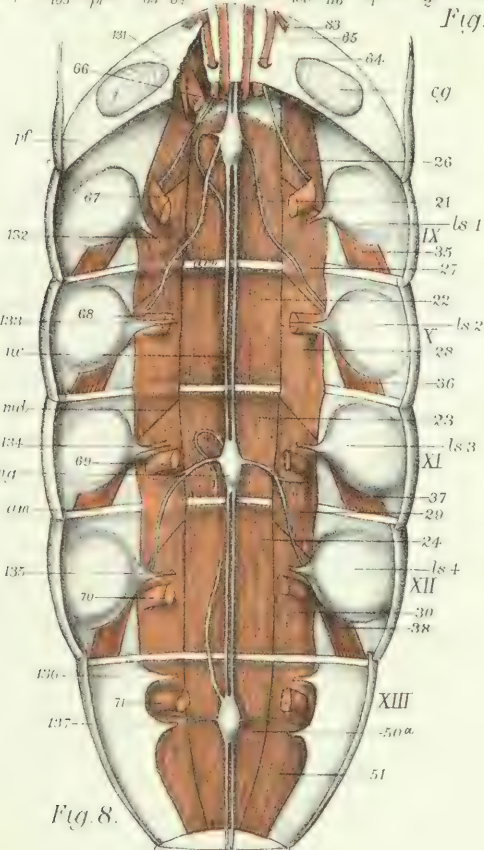


Fig. 7.



PART IV. *Comparison of the Muscular and Endoskeletal Systems of Limulus and Scorpio, and Consideration of the Morphological Significance of the Facts recorded.*
By E. RAY LANKESTER.

I HAVE not attempted to modify the descriptions of the hard parts and the muscles of *Limulus* given by Mr. Benham, and of *Scorpio* given by Miss Beck, so as to obtain a uniformity of nomenclature and numbering for these parts in the two animals. Undeniably the nomenclature which has seemed to be the simplest and most intelligible is at the same time exceedingly clumsy, but that is a reproach which is equally justified in the case of all attempts at the naming of muscles. We have before us, in Parts II. and III. of this Memoir, a systematic description of the muscles of the King Crab and the Scorpion which can serve as a basis for comparisons between the two animals.

Like all Arthropoda these animals have lost entirely the circular muscular layer of the body-wall which their Vermian Chætopod-like ancestors possessed¹. This suppression of the circular muscular layer is correlated with the development of the great tergal and sternal sclerites, and the consequent incompressibility of the body. The muscles of the body-wall are entirely longitudinal or else dorso-ventral. The muscles are practically divisible into three great groups, viz. those of the body-wall just referred to, those of the limbs, and those of the viscera (pharyngeal and veno-pericardiacs, and intrinsic muscles). Those which pass from one or other part of the body-wall to the limbs are by far the most bulky and numerous group of the three, in both *Limulus* and *Scorpio*.

Neither *Limulus* nor *Scorpio* is in a primitive or archaic condition, so far as the segmentation of the body and the differentiation of its appendages are concerned. We have not to deal in either case with a simple condition, but in each with a highly specialized condition. Presumably the ancestors of the Arachnida, in which class both *Limulus* and *Scorpio* find their places, were provided with a completely segmented body, consisting of at least eighteen separately movable somites, a prostomium, and a postanal spine. Each of the eighteen segments at a remote period of the ancestry carried a pair of appendages. The musculature at this time was no doubt very simple and regular, exactly repeating itself in each successive body-ring. Assuming that dorsal and ventral sclerites had been developed on each segment, and that the coxæ of the limbs were chitinized, it is yet probable that at such an early stage no representatives of the remarkable floating cartilages or "entochondrites," which form so characteristic a feature in the organization of living Arachnida, had yet been brought into existence. The simple musculature may be supposed to have consisted of—1, a series of paired dorsal longitudinal muscles passing from tergite to tergite of each successive

¹ Unless the latero-dorsal muscles of the mesosoma of Scorpions (15 to 20 in Miss Beck's enumeration) may be considered as representing that layer.

segment; 2, a similar series of paired longitudinal ventral muscles; 3, a pair of dorso-ventral muscles passing from tergite to sternite in each segment, possibly derived from the circular muscular layer external to the longitudinal which the soft-bodied fore-runners of these chitinized Arthropods must have possessed; 4, a set of muscles moving the coxa of each limb in its socket, and consisting of probably an anterior and posterior dorso-coxal from the tergite of each segment to the coxa of each of its two limbs, and a similar anterior and posterior sterno-coxal muscle passing from the sternite of each segment to the coxa of each of its two limbs; 5, a pair of muscles in each segment passing from the floor of the great dorsal blood-sinus (the pericardium) to the roof of the great ventral blood-sinus which expanded on each side over the bases of the appendages (veno-pericardiacs); 6, muscular bands radiating from the wall of the pharynx to the adjacent tergite and sternite.

The departure of both *Limulus* and *Scorpio* from such an ancestral plan is probably to be traced for a certain distance along a common path.

The confluence of the prostomium and the six anterior tergites to form a prosomatic carapace, and the suppression of appendages on the six segments of the metasoma, as well as the specialization of the six pairs of appendages of the prosoma, as elongate ambulatory and grasping organs, and of the six pairs of appendages of the mesosoma as flattened natatory and branchial organs, was common to the ancestors of both *Limulus* and *Scorpio*. This modification of form and specialization of body-regions entailed a corresponding modification of the muscular system. The dorsal and ventral longitudinal muscles of the prosoma were suppressed, as well as those of the aborted metasomatic appendages. The muscles of the prosomatic limbs acquired larger size, and became subdivided, whilst those of the mesosomatic limbs retained their simplicity.

Coming to the actual form of the living Scorpions and King Crabs, we find that the former has retained the separate chitinized segments of the mesosoma and metasoma, whilst it has modified the four posterior pairs of mesosomatic appendages so that they are no longer movable; accordingly the Scorpions retain both the dorsal and ventral longitudinal muscles of the mesosoma, whilst the muscles of the four posterior pairs of mesosomatic appendages (the lung-books) are aborted. *Limulus*, on the other hand, has retained both its prosomatic and mesosomatic appendages in full locomotor activity, and not only are the hypothetical ancestral muscles of the latter appendages present, but additional and very powerful muscles (the thoraco-branchials) have been developed; at the same time *Limulus* has undergone a very peculiar modification of the tergites of the mesosoma and metasoma resulting in the formation of what is called "the abdominal carapace." Consequently the dorsal longitudinal muscles are entirely suppressed, with the exception of the powerful hinge-muscle (connecting the anterior and the posterior carapace) and the interentapophysial muscles, which all arise from the pair of great entapophyses of the prosoma, and are inserted into entapophyses of the mesosoma, and may be regarded as modifications of the dorsal longitudinal intersegmental muscles.

The ventral longitudinal muscles of the mesosoma are retained, whilst the metasoma is altogether in a reduced or degenerate condition.

One special feature resulting from the concentration of the skeletal covering of *Limulus* in two great tergal plates (the anterior and posterior carapaces) is the development of muscles connected with the limbs and other sternal parts of the mesosoma, which do not keep within the limits of the segment to which one end of such muscle may be attached, but take a long course forwards so as to receive their dorsal attachment either in the prosomatic carapace or in portions of the meso-metasomatic carapace anterior to (in other cases posterior to) the segment of their insertion. Such vertical-oblique muscles may possibly in some cases be regarded as resulting from dislocations of normal vertical muscles, which normally arise, and are inserted in the tergum and sternum of one and the same segment. But, generally speaking, it seems necessary to regard such muscles as new developments, since it is difficult to imagine the steps by which a muscle (apart from a movement of the hard pieces of tergum or sternum to which it was primitively attached) could acquire new attachments outside the segment to which it properly belongs.

The great entapophyses (*Ent*¹) of the prosoma of *Limulus* appear to furnish an important instance of the removal of a skeletal piece from association with the segment to which it primitively belonged, and of its incorporation by fusion with a segment in front of it. Such a transference is familiar enough in the higher vertebrata in the case of the transference of the centrum of the atlas vertebra to the next following segment, where it appears as the odontoid process of the axis-vertebra. Apparently in the same way the entapophyses of the first mesosomatic segment of *Limulus* have been detached from the rest of the dorsal sclerite of the first mesosomatic segment and have been incorporated with the prosomatic carapace, thus taking up a position *in front of* the great tergal hinge to which they were primitively posterior. The attachment of muscles to these large entapophyses, and the serial relations of those muscles and of the muscles attached to the area of the first segment of the mesosoma and of the succeeding mesosomatic segments, is decidedly in favour of the supposition that such a transference has taken place. The attachment of the external branchials of *Limulus* (20), and of the two most anterior of the mesosomatic dorso-ventrals (12), gives important evidence in this matter. When we adopt the view that the prosomatic entapophyses are really the entapophyses of the first or genital segment of the mesosoma, and that correspondingly the following five pairs of entapophyses belong respectively to the five succeeding segments of the mesosoma, whilst the sixth pair of entapophyses belongs to the metasoma, the interpretation of the series of muscles attached to them and to the adjacent parts of the tergum becomes intelligible. This view corresponds with that which I had put forward as the result of a study of the hard parts only, in my article "*Limulus* an Arachnid" (Q. J. Micr. Sci. 1881). See woodcut, fig. 1, of the tergal surface of *Limulus* in that article.

The hollow in-sinkings of the chitinous surface of the body, in connexion with the attachments of muscles so largely developed in *Limulus*, form, it may be noted, an Arachnid character. Such cupping of the chitinous integument is seen in the Arachnid *Thelyphonus*. The remarkable hollow tendons of *Limulus* originating as stigmata at the bases of the mesosomatic appendages, and giving attachment to the great thoraco-branchial muscles, are of the same nature as the dorsal entapophyses.

These oblique or vertico-oblique muscles of *Limulus* (the thoraco-branchials) constitute the chief difference between the musculature of *Limulus* and *Scorpio*. They are unrepresented in *Scorpio*; they cannot be derived from any muscles existing in that animal or in the hypothetical common ancestor of the Arachnids. They must be regarded as *new* structures, special to the Limuloid modification of the type.

It may be laid down as a guiding principle in the study of phylogeny or the genealogies of animals and plants, that organs do not arise *de novo*, and that apparently new organs are to be traced to pre-existing organs, by the modification (division, expansion, atrophy, or other change) of which they have gradually been brought to their present condition. It is questionable, however, whether this principle can be applied to the phylogeny of muscles. Muscular tissue apparently may replace, and does actually replace, ordinary fibrous or other connective tissue, and thus a muscle may be formed where no muscle previously existed. The development of striped muscular tissue in *Limulus* is exuberant in a remarkable degree, and it is by no means an unwarrantable assumption that in this and in other Arthropods new muscular connexions are brought about by the gradual substitution of muscular for connective tissue. This of course merely implies that muscular tissue, like connective tissue, fine blood-vessels, and nerves, is not liable to restriction in the direction and manner of its growth in strict accordance with the segmentation impressed upon an animal in early stages of its genealogical history and inherited in a more or less perfect form at the present day.

Nature of the Entochondrites.—I have come to the conclusion that the prosomatic and smaller posterior entochondrites, both of *Limulus* and *Scorpio*, are, in so far as their "body" or central part is concerned, merely the original subepidermic connective tissue of the sternal surface of the segments in which they occur, which has become thickened and cartilaginous, and has at the same time floated off, as it were, from the sternal surface and taken up a position deeper, that is to say nearer the axis of the animal, than that which it originally occupied. This interpretation of the entochondrites is favoured by the fact that the small mesosomatic entochondrites of *Limulus* (and the single mesosomatic entochondrite of *Scorpio*) are in close relation to the sternal epidermis and lie beneath the nerve-cords, although the large prosomatic entochondrites of both *Limulus* and *Scorpio* have the nerve-cords below them. Supposing the detachment from the sternal integument of the mass of connective tissue forming the prosomatic entochondrite to have occurred at a period when the nerve-cords were still quite lateral in position (as they remain to this day in *Peripatus*) in the prosomatic region, although

they had converged towards the median line in the mesosoma (as we see is the case in representatives of allied groups, such as *Serpula*), then there would be no difficulty in accounting for the present position of the nerve-cords in relation to the entochondrites by supposing that they tended subsequently to the detachment of the prosomatic entochondrite to take up a position more and more coincident with the median ventral line, although in the mesosoma they had already taken up such a position. Accordingly the nerve-cords in the prosoma would be able to take up their present position beneath (*i. e.* ventrad of) the prosomatic entochondrite, whilst in the mesosomatic region the nerve-cords, already occupying a median position, would necessarily remain superior (*i. e.* dorsad to) the mesosomatic entochondrites. Such movements of masses of tissue as are here postulated are entirely in accordance with well-established conclusions. There is no doubt that the double nerve-cord of Arthropods and Chaetopods owes its double character to the fact that it originated as two widely separated lateral tracts of nervous tissue, which have gradually (in the course of ancestral development) converged towards the middle line, as is also the case in the independent phyla of the Leeches and the Molluscs.

There is also no doubt that these nerve-cords originated *in* the epidermis, and that in some animals they still remain actually as thickened ridges of that layer, whilst in a large majority they have become detached from that epidermal connexion (although maintaining it in their embryology), and have sunk inwards through connective tissue and muscle until they lie well within the body. There is no animal in which this detachment of the nerve-cord from its primitive relation to the epidermis is carried so far as the Scorpion, where, as seen in the sections drawn in Pl. LXXXI. figs. 1, 2, *nn*, the nerve-cord attains in the mesosoma almost an axial position. Just as the mass of tissue called nerve-cord can move from its primitive relations, so, it appears reasonable to admit, can other tissue-masses, and accordingly amongst others the dense subepidermal entochondrites. Possibly the application of this principle of the in-sinking of primitively subepidermal skeletal tissue may throw some light upon the skeletal structures of Vertebrata. At any rate it is a legitimate hypothesis in regard to the entochondrites of Arthropoda, and enables us to understand the nature of these bodies and the muscles attached to them. The muscles attached to the entochondrites are primarily the muscles attached to the midsternal region of the segments in which such entochondrites occur. This is obvious enough with regard to the small mesosomatic entochondrites of *Limulus*, and it will be found to give an intelligible explanation of the muscles attached to the great prosomatic entochondrite.

It is to be noted that the inter-entapophysial ligaments which run on each side, right and left, along the dorsal surface of *Limulus*, passing from one entapophysis to the next, are of similar nature and origin to the entochondrites. They represent a tract of detached subepidermal connective tissue belonging to the tergites, just as the entochondrites represent subepidermal connective tissue of the sternites.

In connexion with this matter it is important to observe that the attachment of all muscles in all Arthropods, *apparently* to cuticular plates or sclerites formed by the epidermis externally, is *really* an attachment to subepidermic connective tissue. No muscle ever comes into direct relation with epidermic cuticle, even when that cuticle is in the form of a hollow ingrowth (entapophysis) or a solid ingrowth (entosclerites of Scorpion). The epidermic cuticle is always clothed internally with fibrous connective tissue, and this is the intermediary of the attachment of muscle and sclerite. Accordingly it is not difficult to conceive of the connective tissue in any special case assuming large proportions and dense substance, and if supported otherwise than by its adhesion to an epidermic sclerite, losing by degrees all connexion with such a sclerite.

Applying these considerations to the case of *Limulus* and *Scorpio*, we come to the conclusion that the muscles attached to the entochondrites are:—1st, representatives of the serial longitudinal intersegmental muscles of the ventral series; 2nd, representatives of the serial dorso-ventral muscles; 3rd, more especially the primitive sterno-coxal muscles of the limbs; and 4th, the primitive sterno-buccal muscles.

In both *Limulus* and *Scorpio* the prosomatic entochondrite or plastron, as it is more shortly called, represents the midsternal area of several segments fused—probably, in both cases, of all the prosomatic segments; though possibly in *Scorpio* the first segment is not included, since muscles to the chelicerae do not arise from the plastron in *Scorpio*, and a longitudinal muscle (84) extends from its anterior subneural processes on each side to be inserted into a small postoral sclerite. Probably also the plastron of *Scorpio* includes the midsternal area of the genital (or first mesosomatic segment), since there is no separate entochondrite to that segment as there is in *Limulus*, whilst there is such a distinct entochondrite to the next or pectinigerous segment. This view is further borne out by the fact that a pair of muscles (the operculo-plastrals 85) similar to the muscles (the internal branchials 48) which pass from the entochondrite into each of the mesosomatic appendages of *Limulus* (represented also in the pectinigerous segment in *Scorpio*) pass from the hinder part of the prosomatic plastron of *Scorpio* to the genital operculum.

Relative Condition of the Mesosomatic Appendages in Scorpio and Limulus: Lung-books and Gill-books.—The six flattened, mesially fused, mesosomatic appendages of *Limulus* are represented by two pairs of appendages and four pairs of respiratory lamelligerous cavities in *Scorpio*. The diminutive size of the genital operculum of *Scorpio* as compared with that of *Limulus* accounts for its incomplete musculature; but such muscles as it has (the operculo-plastrals 85) agree with the more primitive among the muscles of the same appendage in *Limulus*. A similar statement is true of the pectines or second pair of mesosomatic appendages of *Scorpio* as compared with the second pair in *Limulus*. The four pairs of lung-books of *Scorpio* are not entirely devoid of muscles; the post-stigmatic muscles passing from the posterior edge of the stigma of each lung to the posterior border of the sternal region of the same segment

appear to me to correspond to the internal branchials (48) of the four corresponding pairs of limbs in *Limulus*.

The view which I advocated in my essay "*Limulus* an Arachnid," as to the mode of conversion of an external lamelligerous appendage into the hollow lamelligerous lung of *Scorpio*, no longer commends itself to me. A much simpler and, as it appears to me, a thoroughly satisfactory explanation of the relationship of the two organs has suggested itself in the course of the investigations here recorded, and is supported also by embryological data. In the essay above referred to, I suggested that by the enlargement of the hollow stigmata connected with the thoraco-branchial muscles of an ancestral Scorpion, resembling *Limulus* in having branchigerous appendages on the mesosoma and thoraco-branchial muscles, the branchigerous appendage might come to lie in the pit or hollow of the tendon, and eventually the hollow might enclose it. The conversion of the in-sunken appendage into a hollow air-holding sac and the corresponding conversion of the surrounding pit into a closed blood-holding space, involved serious difficulties which were indeed fatal to the hypothesis. When I found that the muscle (veno-pericardiac) attached to the apex of each lung-sinus in *Scorpio* had no possible relation to the thoraco-branchial muscles of *Limulus*, but was represented in *Limulus* by exactly similar veno-pericardiac muscles, I gave up my overstrained hypothesis. I trust that the failure of my previous suggestion will not unduly prejudice those interested in this subject against that which I now advance. Since my memoir "*Limulus* an Arachnid," Dr. MacLeod of Brussels has published some speculations on this subject, in which he puts forward an ingenious theory of his own as to the mode in which the lamelligerous appendage of a *Limulus*-like animal might be converted into the lamelligerous lung-book of an Arachnid. I will not enter into a discussion of Dr. MacLeod's hypothesis, but will merely point out that inasmuch as it deals with *not* the less modified lung-book of Scorpion, but the more modified lung-book of the Araneina, it is unsatisfactorily elaborated. The lung-book of *Scorpio* has a definite axis carrying the leaf-like lamellæ, and corresponding to the axis of the same animal's pecten. Such an axis is not present in the Arancine lung-book, and yet must be accounted for as a primary structure in any theory as to the origin of these organs.

The hypothesis which I now put forward is perfectly simple, and leaves, I think, nothing to be desired. In *Limulus*, as in *Scorpio*, there is on each side of the sternal surface a great blood-sinus in free communication with the lamelligerous organs. Let us suppose such to have been the case in the common ancestor of these two animals, and let us suppose that this ancestor possessed six pairs of mesosomatic appendages, of which five were lamelligerous and intermediate in form between the pectens of Scorpion and the recent *Limulus* appendage. Now suppose that in the Scorpion branch of the family the mesosomatic appendages grew relatively smaller and smaller, were no longer locomotor organs, but purely respiratory, and served for aerial rather than aquatic respiration. If we imagine the four hinder pairs of these reduced appendages to have

taken on *in the embryonic condition* a very common trick of growth, viz. an inward growth of invagination, so that they grew *into* the Scorpion's body, turning their outside in, just as a glove may have all its fingers and part of the hand turned outside in—then we should have without further alteration the exact condition of the modern Scorpion's lung-book. The appendages growing thus inwards by introversion (instead of outwards, as is normal) would simply be tucked or pushed into the great blood-sinus, which would constitute around each in-grown appendage a venous sac just as we actually find in the Scorpion. The most familiar case of inward growth taking the place of outward growth is in the development of the *Tænia*-head upon the cyst of the hydatid in such a form as *T. solium*. The head develops in a perfectly normal way, excepting that it is completely introverted, pushed outside in, and at a certain stage it becomes everted, as it should have been from the first, had it retained in growth its ancestral relations. The cause of the introverted growth of the *Tænia*-head on its cyst is very probably external pressure; in fact the growing mass of tissue takes the direction of least resistance, and grows *into* the cyst instead of *out from* it. It is not at all improbable that such a condition of external pressure might in the first instance have induced the inward growth, during development, of the lung-books of the Scorpion. The development of the young Scorpion goes on at the present day under very remarkable conditions, actually in the ovary, the egg-cell never moving from its place of origin until it has grown into the fully-formed Scorpion; the pressure of the ovarian tunic upon the surface of the growing embryo must be considerable, and is at any rate a possible cause of the invagination of the four hindermost pairs of mesosomatic appendages in the first instance. Probably the lamelligerous appendages of the young Scorpions, of a certain stage in the ancestry of recent Scorpions, were everted and assumed the normal relations of appendages as external processes of the body-wall as soon as the young were born. But as the lamelligerous appendages were only required to act as aerial respiratory organs, it would be no disadvantage, but positively an advantage, that they should *remain* in the introverted condition; and this at last has become the permanent condition. This hypothesis accounts for the fact that the four pairs of lung-books do not ever appear on the surface of the embryo Scorpion as up-standing appendages. They are from the first introverted, and remain so. It also agrees with the disposition of the cuticularized surfaces of the Scorpion's lung-book as seen in the adult. The cuticularized surface remains in the in-pushed as it is in the out-growing appendage, the surface in contact with the air. Each bag-like lamella is introverted together with the axis of the limb; and one cannot better picture to oneself the relative conditions of out-growth and in-growth than by fixing a kid glove by the margin of its opening to the margin of an opening of the same size on the outside of a box. The coloured surface of the kid will represent the cuticle, the fingers the lamellæ, the hand the axis. Thus the glove will represent a lamelligerous appendage, standing up on the ventral surface of an Arthropod, its cavity communi-

cating with the cavity of the venous sinus of the animal, as the cavity of the glove does with that of the box.

Now, without removing the glove, push all the fingers from their tips inwards into the hand, and then the hand into the box, so as completely to turn the glove outside in. Thus the glove will represent the appendage when introverted into the venous sinus as in the modern Scorpions.

The tips of *some* of the introverted lamellæ of the Scorpion's gill-book have acquired laterally, but not in every part, an attachment to the wall of the venous sac into which they have pushed their way. These attachments and the relation of blood-space, air-space, and cuticle in the lung-lamellæ of *Scorpio* are shown in the transverse sections drawn in Pl. LXXXI. figs. 3 & 4.

New or non-hereditary Muscles of Limulus.

The muscles which, if we admit the legitimacy of the hypothesis of *de novo* formation of muscles, must be regarded in the case of *Limulus* as having come into existence subsequently to the divergence of that animal and the Scorpion from a common ancestry, and by a process of tissue-change, *not* by a modification of already existing muscle, are the following, viz. the whole series of dorso-ventral muscles which run obliquely from the dorsum of one segment to the sternum of another. Such are the great dorsal entapophysial-plastral (1), and its branches (83, 84, 85, 86, 87), also the ventral entapophysis plastral (2) and its slips (103 to 106); further the dorso-lateral plastro-entapophysials (53), the metaplastro-entapophysials (56), the entapophysio-metaplastrals (72); the oblique slips (74, 75, 76, 77); the ventral entapophysiopygals (9), and the whole series of branchio-thoracic muscles (18, 19).

In *Scorpio* it does not appear that it is necessary to assume a new origin for muscles on a similarly large scale. The muscles just noted in *Limulus* all have relation to the peculiar consolidation of the mesosomatic region and the combination of natatory with branchial functions in the appendages of that region of the body. In the Scorpion, on the other hand, it is the limbs of the prosoma which have become especially developed and modified as compared with the archaic plan. In *Limulus* the limb-muscles of the prosoma do not require the hypothesis of any new formations; they can be derived by a process of subdivision from an original hypothetical series of limb-muscles, each limb having the muscles which move its coxal segment attached to the adjacent area, either of tergum or entochondrite (plastron), which undoubtedly represents the original segment to which the particular limb belongs. Not so, however, in the Scorpion, where the muscles attached to the coxæ of the prosomatic limbs are of great size and displaced to such an extent that it cannot be with any confidence asserted that each coxa has attached to it merely the modified representatives of the same series of muscles which we find repeated in each successive coxa of *Limulus*. The disentanglement of these muscles and their reference to the two categories of (*a*) primary and (*b*)

secondary (or newly originated) muscles, would furnish ample field for speculation and ingenuity. An important difference between the musculature of the coxo-sternal joint of the prosomatic limbs of *Limulus* and *Scorpio* is to be found in the fact that in *Scorpio*, as shown by Miss Beck, we have muscles arising from the prosomatic tergite, and inserted into the deutomerites of some of the limbs (106, 107, 108), and others arising from the ventral entosclerites also inserted into the deutomerites of limbs (100, 101, 102, 103), whereas in *Limulus* no deutomerite appears to receive any muscle from the body-wall, such muscles being confined to the protomerite (coxa).

Muscles arising from the Plastron or Prosomatic Entochondrite in Limulus and Scorpio.—When we exclude the obliquely-running antero-posterior muscles, which pass from the tergum of the mesosomatic carapace of *Limulus* to the prosomatic plastron, namely, the great dorso-entapophysial (1) and its branches 83, 84, 85, 86, 87, those from the great entapophyses (originally part of the mesosoma) 53 and 54, and from the two following entapophyses 56, 72 (Pl. LXXV.), we find that the muscles attached to this body in both *Limulus* and *Scorpio* are practically the typical muscles of the ventral surface of the prosoma, and are strictly comparable in the two animals. At either end we find longitudinal ventral muscles (anteriorly in *Scorpio* only) connected with similar entochondrites in the following segments: dorsally are representatives of the dorso-ventral segmental muscles proper to the prosoma; and laterally muscles attached to the coxæ of the prosomatic limbs. There are three pairs of vertical tergo-plastral muscles in the *Scorpio* (63, 64, 65), and these correspond to the muscle 52 of *Limulus* (Pl. LXXV.), and have no other representative, their place being taken by oblique muscles, whose tergal attachment is in the mesosoma. Possibly, however, the muscle 64 of the *Scorpio* (Pl. LXXVIII. figs. 6 & 7) may be considered as the equivalent of the muscles 53 and 54 of *Limulus*, in which case we should have to suppose that in the *Scorpio*, as well as in *Limulus*, the fusion of a piece of the first mesosomatic tergite with the prosomatic carapace had taken place. There seems to be no representative in the *Scorpio* of the anterior vertical tergo-plastral muscles of *Limulus*, 49, 50, 51 (Pl. LXXV.), and in fact the most anterior region of the plastron in the *Scorpio*, as has been before pointed out, appears to stop short of the anterior region of the prosoma, whereas in *Limulus* it reaches anteriorly to the full limit of the ventral surface.

When we compare the muscles passing from the plastron to the limbs in *Limulus* and *Scorpio*, we find again reason to suppose that the plastron of the latter does not comprise the ventral surface of the first prosomatic segment, although it does do so in *Limulus*. In fact, we have no muscles from the plastron to the first pair of limbs in *Scorpio*, whilst in *Limulus* we have two such muscles, viz. Nos. 30 and 31. In place of these, in *Scorpio* we have muscles which arise from the preoral entosclerite (96, 97, 98). Contrariwise there are no muscles of ventral origin in *Limulus* which are inserted into

the first pair of prosomatic limbs, except those above mentioned as arising from the plastron (30 & 31).

In the case of the following five pairs of appendages, the muscles attached to them and to the plastron may be exhibited for comparison in a tabular form in the two animals: in the series referring to *Limulus* all are attached to some part of the large coxa; in the series referring to *Scorpio*—*cox.* signifies coxal insertion, *deut.* insertion into the deutomerite, and *arthr.* insertion into the arthrodial membrane between the adjacent coxæ or the coxa and sternal sclerite.

	<i>Limulus.</i>	<i>Scorpio.</i>
I.	30 and 31	none.
II.	32, 33, 34	72 (cox.), 75 (cox.), 76 (cox.).
III.	35, 36, 37	73 (deut.), 74 (cox.).
IV.	38, 39, 40	77 (deut.), 78 (cox.), 79 (arthr.).
V.	41, 42, 43	80 (deut.), 81 (arthr.).
VI.	44, 45, 46, 47	82 (deut.), 83 (arthr.), 86 <i>a</i> (arthr.).

In carrying out the comparison of the muscular relations of the plastron in *Scorpio* and *Limulus*, it is necessary, in the next place, to point out that in *Scorpio*, a muscle (85) passes from the hinder border of the body of the plastron into the genital operculum. No such muscle occurs in *Limulus*. But a similar muscle (the first of the series numbered 48 in Mr. Benham's description) passes from the second entochondrite of *Limulus*, or entochondrite of the genital segment, into the genital operculum. Now, in *Scorpio* there is no separate entochondrite in the genital segment, although there is a separate entochondrite in the next following (the pectinigerous segment) corresponding to the second mesosomatic entochondrite of *Limulus*; and this entochondrite of the second mesosomatic segment in *Scorpio* gives origin to muscles which descend into the pecten (90, 91, 92), and correspond to the muscle 48 in the second mesosomatic segment of *Limulus* as described by Mr. Benham. Hence it seems extremely probable that the difference between *Limulus* and *Scorpio* as to the muscle and entochondrite of the genital segment is to be accounted for by the fact that in *Scorpio* the entochondrite of that (the first mesosomatic) segment has fused with the great prosomatic entochondrite or plastron. This is in accordance with other indications of a tendency to draw up structures to the prosoma, noticeable in the Scorpion, *e. g.* nerves. Accordingly the muscle 85 of *Scorpio* (the operculo-plastral) is the equivalent of the internal branchial (48) of the genital segment of *Limulus*.

The longitudinal muscles attached to the plastron in *Limulus* and *Scorpio* belong necessarily (when we exclude the adventitious or secondary muscles descending obliquely to it from the tergites of a posterior region) to the typical ventral series. They may be compared as follows:—

<i>Limulus.</i>	<i>Scorpio.</i>
a. Plastro-buccal, 67	Absent: but represented by muscles attached to the preoral entosclerite, 99.
Part of no. 5?	b. Muscle from subneural part of plastron to entochondrite of 2nd mesosomatic segment, 86.
That part of muscle no. 5 between the 1st and 2nd mesosomatic entochondrites . . . }	c. Muscle from supraneural part of plastron to same entochondrite.

When thus examined in detail a very close correspondence is found between the muscles arising from the plastra of the two animals. Perhaps the most important conclusion to which we are led by the comparison is that the cartilaginous body known as entosternite, entochondrite, or plastron in *Scorpio* represents the sternal surface of one segment *less* in front, and of one *more* behind than does that of *Limulus*. In *Scorpio* it corresponds to segments 2 to 7 inclusive; in *Limulus* it corresponds to segments 1 to 6 only.

There are, no doubt, other relations in which the anatomical facts set forth in the systematic descriptions and figures of Mr. Benham and Miss Beck might be considered, so as to give them significance. But for the present I must leave this task, and rely upon others to make use of some of the many data given in these descriptions.

PART V. *Notes on Certain Points in the Anatomy and Generic Characters of Scorpions.*
By E. RAY LANKESTER. (Plates LXXX. to LXXXIII.)

a. *The Venous System.*

WHEN I first observed the pericardio-ventral (or veno-pericardiac) muscles of the Scorpions, as shown in Pl. LXXX. fig. 15, *pp*¹, *pp*², &c., and Pl. LXXVII. figs. 1, 4, & 5; also in Pl. LXXVIII. figs. 8 & 9, I discovered that they are to a large extent hollow, being excavated funnel-wise both at their pericardial attachment and at their insertion into the wall of the venous sac-like dilatation which surrounds the insunken lung-book (see the sections, Pl. LXXIX. fig. 10, and Pl. LXXXI. fig. 2, *ppm*). I was led to think it possible that these hollow muscles formed a direct channel of communication between the pulmonary venous sacs and the pericardium, the blood being returned through them to the heart in an aerated condition. Although similar muscles exist in *Limulus*, the channel which the blood pursues on its way from the gills to the heart is quite independent of them, and in *Limulus* they are solid. This led me to attempt, by

means of injections, an exploration of the great veins of the Scorpions. My observations were made upon freshly-killed specimens of *Androctonus funestus*, which I obtained from North Africa for the purpose. I used as injecting material sometimes soluble Berlin blue, sometimes a mixture of wax, tallow, and turpentine coloured by vermilion. By introducing the injection at various points, especially into the venous sacs surrounding the lungs (by means of a very fine nozzle) I satisfied myself that there is no passage through the pericardio-ventral muscles to the pericardium. The chief veins leading from these dilatations of the ventral blood-sinus to the heart run up the sides of the body quite superficially, lying outside the longitudinal dorsal muscles between these and the integument. They enter the pericardium at its dorso-lateral angles right and left (Pl. LXXXI. figs. 1 & 2, *svsl*). Deeper than the longitudinal dorsal muscles is a second series of veins parallel to the first; but these do not open into the pericardium.

In a pale-coloured *Androctonus*, the position of the main venous trunks may be seen by transparency when they are injected either from the pericardium or from one of the circumpulmonary sinuses. Views of a specimen thus injected are given in Pl. LXXX. figs. 1, 2, 3. On the ventral surface (fig. 3), the injection shows at intervals near the mid-line, and the edge of the circumpulmonary sinuses are also seen. Internally it is found, on dissection, that the injection, besides occupying numerous large flattened spaces between the lobes of the gastric glands and the genital organs, is chiefly aggregated in two deep-lying latero-ventral longitudinal trunks which dilate around and enclose each in-pushed lung-book. Although the pericardium also is found to be full of the injection and the hollow pericardio-ventral muscles are half-filled (on their pulmonary side) with injection, yet no injection is found to have penetrated along the whole length of these muscles so as to reach through to the pericardium.

On the contrary, the veins connecting the pericardium and ventral longitudinal sinuses are seen when a lateral view of the specimen is taken (fig. 2) to be injected. Here we find a large vein (*svsl*) branching in the prosomatic carapace, returning *some* blood from the coxal glands and the limbs. In the first and second mesosomatic segments small veins (*svsl*¹, *svsl*²) are seen bringing the blood from the genital and pectinigerous segments to the pericardium. In the third, fourth, fifth, and sixth mesosomatic segments these lateral veins are much larger and extend directly from the circumpulmonary venous sacs to the pericardium. They appear also to have wide anastomatic trunks running longitudinally between them. In the first metasomatic segment, the lateral veins have a strongly marked posterior direction, and do not reach the ventral surface.

The arterial system of Scorpions (probably of *Androctonus*) was carefully described by Newport; but he was not able to give a decisive account of either the capillary or venous system, on account of the fact that his specimens were not living, but badly preserved in spirits.

In Pl. LXXX. fig. 15, I have drawn a view from the inside of an actual dissection displaying the tergum and large vessels, pericardium and muscles of *Androctonus*

occitanus (the Spanish Yellow Scorpion). It shows excellently the lateral arteries and the whole series of pericardio-ventral muscles. The blood is pumped by the contractile heart lying within the pericardium (Pl. LXXXI. figs. 1 & 2 *cc*) into these lateral arteries, also into anterior and posterior arteries. The anterior arteries especially accompany the great nerves, and one main trunk is completely reflected ventrally and accompanies the nerve-cords throughout the length of the animal, giving off lateral branches (Pl. LXXXI. figs. 1 & 2 *spa*).

The arteries thus arising branch very abundantly and supply directly every organ, even every muscle, in the body. The finest branches of these arteries are entitled to be termed capillaries. I have described them and the similar vessels in *Limulus*, in my article on the skeleto-trophic tissues of these animals, in the Quart. Journ. Micr. Sci. for January 1884.

The capillaries of the Scorpion (and the same is true for other large Arthropoda, such as the Crayfish) do not reunite, as in Vertebrates, to form a tree of branches which gradually increase in bulk, but they open into more or less irregular spaces, often large and shallow, which surround the chief organs. These may be called, as is the custom, sinuses or lacunæ; but they are truly veins with their own proper walls, though of non-cylindrical form in cross-section. In the region of the prosoma and mesosoma these spaces open into the two large longitudinal ventral veins which have the lung-sacs sunk into them at intervals in the 3rd, 4th, 5th, and 6th mesosomatic segments. A large part of the blood arriving in these great ventral sinuses or veins will come in contact with the delicate lamellæ of the lung-books, and finding its way between the lamellæ, as shown in Pl. LXXXI. figs. 3 & 4, it will be subject to gas-exchange. From these longitudinal ventral trunks the blood then passes in a partially oxygenated condition by the superficial lateral veins (*sesl*, Pl. LXXX. figs. 1, 2, 3) into the pericardium, from whence it is taken by the expanding heart (expanding by the elasticity of its walls after contraction) through its seven pairs of valvular apertures (*vv*, Pl. LXXX. fig. 1, where only five pairs are seen, and *cv*, in Pl. LXXXI. fig. 2) into its cavity and again sent on its round. The main force at work in drawing the blood from the circumpulmonary sinuses of the longitudinal ventral veins into the pericardium, is clearly enough (as in other Arthropods) the same contraction of the heart which expels the blood through the arteries. The contraction of the heart creates a diminution of the tension in the pericardium. But there can be no doubt that both in *Limulus* and in *Scorpio* the pericardio-ventral (veno-pericardiac) muscles exercise an important influence in drawing the blood from the general venous space-system surrounding the viscera into the circumpulmonary sinuses. These muscles probably contract simultaneously with the contraction of the heart, and thus, while tending to keep the pericardium distended, also distend the circumpulmonary sinuses, and cause a rush of blood into those chambers. Valvular arrangements (which, however, I cannot say I have detected) would prevent the distending circumpulmonary

sinuses from drawing upon the blood which has already entered the lateral pericardio-pulmonary veins.

It is not at all improbable that the movements of the body-wall (terga and sterna) in *Scorpio* and of the plastron (prosomatic entochondrite) in *Limulus*, and, perhaps, also in *Scorpio*, exert a considerable influence upon the flow of the blood.

b. *Generic and Subgeneric Characters of Scorpions.*

The numerous species of Scorpions which occur in all parts of the world, excepting the Arctic and Antarctic regions, and as far back in time as the Upper Silurian strata, present a most marvellous uniformity of structure, so that the attempt to divide them into families, genera, and subgenera has been a matter of great difficulty, and has led to very perplexing and contradictory results in the hands of successive systematists. The late Professor Peters appears to me to have indicated the most important divisions which may be instituted among Scorpions on structural grounds. Dr. Thorell has carried the formation of genera and subgenera too far, whilst the older system of Koch is entirely artificial and worthless. No writer on Scorpions has given consistently a clear statement or (what is more to be desired) good figures of the really important structural features of the genera, subgenera, and species proposed or recognized by him; and it is with the object of pointing out *what* are the important points in which Scorpions may vary that the present remarks are published. It is impossible to deal with the genera of Ehrenberg and Leach. Starting with Koch, we find that he bases his system on the number and disposition of the lateral eyes, as follows:—

<i>Scorpius</i>	○ ○
<i>Buthus</i>	○ ○ ○
<i>Atreus</i>	○ ○ ○
<i>Brotheas</i>	○ ○ _o
<i>Telegonus</i>	○ ○ ○
<i>Sisyphus</i>	○ _o ○ _o
<i>Tityus</i>	○ _o ○ _o ○ _o
<i>Androctonus</i>	○ _o ○ _o ○ _o ○ _o

The system is an absolute failure. The number and size of the lateral eyes is not even constant in the same individual (the two sides differing sometimes); much less is it so in species and still less in genera. The only generalization which can be made about the lateral eyes, is that in the Scorpions with triangular sternum, they are *usually* more numerous than in those with pentagonal sternum; but not even in reference to such large sections can a strictly accurate statement of the kind be made.

Peters made a great advance in recognizing the form of the sternum (or metasternite, the equivalent of the chilaria of *Limulus*) as a basis for a primary division of the Scorpions. He combined with the consideration of this character a reference to the dentition of the chelicerae; and thus was led to establish four groups or subfamilies of the family Scorpionidæ (the Linnean genus *Scorpio*), viz.:—

Group I. TELEGONINI.

Sternum linear; two or three lateral eyes; both the fixed and the movable joint of the chelicera have a *single* row of teeth.

Genera:—*Telegonus*, Koch; *Cercophonius*, Peters; *Acanthochirus*, Peters; *Bothriurus*, Peters.

Group II. SCORPIONINI.

Sternum quadrate or pentagonal; both the fixed and the movable joint of the chelicera have a single row of teeth.

Genera:—*Vejois*, Koch; *Brotheas*, Koch; *Scorpio*, Linné in part (= *Scorpius*, Ehr.); *Scorpiops*, Peters; *Urodacus*, Peters; *Hemiscorpion*, Peters; *Ischnurus* (*Sisyphus*, Koch), Gervais; *Opisthacanthus*, Peters; *Dacurus*, Peters; *Opisthophthalmus* (*Atreus*), Koch; *Heterometrus*, Ehr. (= *Buthus* in part, Ehr., not Leach); *Diplocentrus*, Peters.

Group III. CENTRURINI.

Sternum triangular; movable ramus of chelicera with *two* rows of teeth, the fixed ramus with *one* row. Hands of the chelæ spindle-shaped. Often a spine beneath the sting.

Genera:—*Centrurus*, Ehr. (not Koch, = *Tithys* of Koch, *Atreus* of Gervais, not Koch); *Uroplectes*, Peters.

Group IV. ANDROCTONINI.

Sternum triangular; both rami of the chelicera with two rows of teeth. No spine beneath the sting.

Genera:—*Prionurus*, Ehr.; *Buthus*, Leach.

The genera adopted by Peters appear to me to be, in most cases, unnecessary, often not even justifiable as subgenera. He has at the same time rendered great service by pointing out the confusions which have arisen in the use of the generic terms of one author by another, in new and unjustifiable senses.

Thorell has added a number of genera to the already superfluous list, and has modified Peters's classification in what appears to me to be a retrograde spirit. He recognizes four families of Scorpions, viz.:—(1) the Androctonidæ, corresponding to Peters's Androctonini and Centrurini combined; (2) the Telegonidæ, identical with Peters's Telegonini; (3) the Vejovidæ; and (4) the Pandinoidæ, the last two resulting from the breaking up of Peters's Scorpionini on no assigned grounds.

Both Peters and Thorell make use of the presence or absence of a keel on the 6th metasomatic segment as a means of generic distinction, and of other characters even more trivial. The small value of such characters is shown by the fact that the common American Scorpion, the *Scorpio americanus* of De Geer, is sometimes provided with a spine below the sting, and sometimes has none.

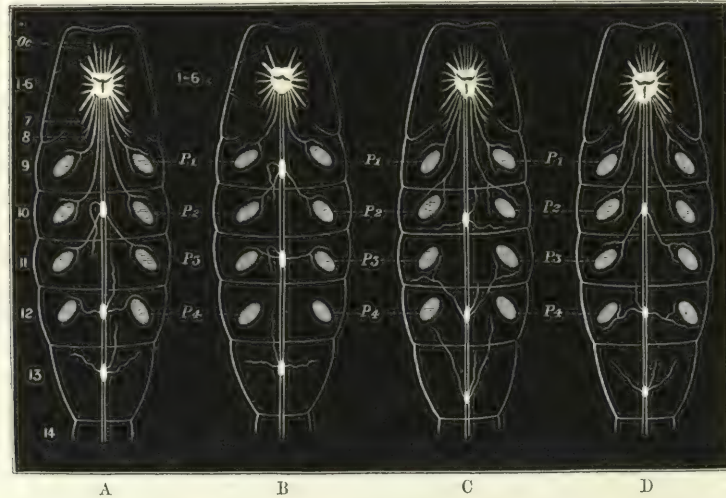
In order to appreciate more clearly Peters's four groups of Scorpions, we may refer to four types which are figured in the Plates accompanying this memoir, viz. for the TELEGONINI the *Telegonus* of Tasmania, Pl. LXXXII. figs. 5, 8, and Pl. LXXXIII. figs. 5, 6; for the SCORPIONINI the *Scorpio cyaneus* and *S. Kochi* of Ceylon, Pl. LXXXII. figs. 1, 10, 19, and Pl. LXXXIII. figs. 9, 10; for the CENTRURINI the *Androctonus americanus*, Pl. LXXXII. figs. 6, 13, 17, and Pl. LXXXIII. figs. 3, 4; for the ANDROCTONINI the *Androctonus funestus* of North Africa, Pl. LXXXII. figs. 2, 14, 15, and Pl. LXXXIII. figs. 1, 2.

My observations, which relate not only to the characters made use of by Peters, but also to two points of internal structure, viz. (a) the disposition of the segmental ganglia and their great nerves and (b) the sculpturing of the lamellæ of the lung-books, have led me to the conclusion that the existing species of Scorpions should be grouped in two and not in four primary divisions; the first group, or Scorpionini, corresponding to Peters's Telegonini and Scorpionini combined, whilst the second group, the Androctonini, correspond to his Centrurini and Androctonini combined.

It appears that the linear compressed sternum of the Telegonini may be regarded as only an extreme form of the broad pentagonal sternum of the Scorpionini. In both series there is but a single row of teeth in each ramus of the chelicera, except a single tooth of a second row on the movable ramus in some species of *Telegonus* (Pl. LXXXIII. fig. 7). But what is of far more importance is that in both Telegonini and Scorpionini the ganglia of the nerve-cord and their off-springing nerves are arranged as shown in the woodcut, fig. 2, B, whereas in the Scorpions of Peters's groups Centrurini and Androctonini these structures have the arrangement shown in drawing, fig. 2, A, C, D (p. 378). This difference may be described by saying that in the Scorpionini (incl. Telegonini) only the region of the first pair of lung-books is innervated from the

prosomatic ganglion, and the first of the two mesosomatic ganglia lies in the third mesosomatic segment, whilst in the Androctonini (incl. Centrurini) both the regions of the first and of the second pairs of lung-books are innervated from the prosomatic ganglion, and the first mesosomatic ganglion lies in the fourth mesosomatic segment. The broad first segment of the metasoma has a ganglion in both cases.

Fig. 2.



Diagrams of the arrangement of the chief nerves and ganglia in various Scorpions.

- A. *Androctonus (Prionurus) funestus* and several Androctonidæ.
- B. *Butkus cyaneus* and Euscorpionidæ and Telegonidæ.
- C. First specimen of *Androctonus (Prionurus) occitanus*.
- D. Second specimen of *A. occitanus*.

1-6, the six segments of the prosoma. 7-12, the six segments of the mesosoma. 13, 14, the two first segments of the metasoma. P_1 to P_4 , the four pairs of lung-books.

This generalization is based on the examination of the nerve-ganglia of two species of Telegonini (one from Coquimbo, the other from Tasmania) of *Scorpio italicus*, *Scorpio cyaneus*, and *Brotheas subnitens* on the one hand, and of those of *Androctonus funestus*, *A. occitanus*, *A. americanus*, and *A. hottentotus* on the other hand.

An examination of the sculpturing of the chitinous surface of the lamellæ of the lung-books in the same species has shown further that all the Scorpionini (incl. Telegonini) have simple punctate ornament, whilst all the Androctonini (incl. Centrurini) have reticulate ornament in addition to punctiform. The latter is drawn in Pl. LXXXI. figs. 5 and 6, the former in Pl. LXXXI. fig. 7.

I should therefore propose to systematize the Scorpions as follows:—

Class ARACHNIDA.

Grade A. *Delobranchia* (*Limulus* and Eurypterines).

Grade B. *Embolobranchia*.

Order 1. SCORPIONIDEA.

Order 2. PEDIPALPI.

Order 3. ARANEIDEA.

Order SCORPIONIDEA.

Fam. unic. SCORPIONIDÆ.

Subfamily I. SCORPIONINI.

Sternum (metasternite) pentagonal, quadrate, or compressed antero-posteriorly, and divided into two narrow triangular pieces, right and left (= *chilaria* of *Limulus*).

Nerves to the region of the first pair of lung-books descending from the prosomatic ganglion-mass. Nerves to the region of the second pair of lung-books supplied by a ganglion lying in the third segment of the mesosoma.

Ornament of the lamellæ of the lung-books punctiform.

A single row of teeth to each ramus of the chelicera; rarely one tooth of a second row on the movable ramus.

Genus 1. SCORPIO.

Char. Sternum pentagonal or quadrate.

Subgenus EUSCORPIUS.

Char. Lamellæ of the pectens very few; lateral eyes two; spiracles *oval*; tail slender. Type *Euscorpius italicus*: South Europe. (Pl. LXXXII. fig. 3.)

Subgenus BUTHUS (= *Heterometrus*, Ehr.).

Char. Lamellæ of the pectens more numerous; lateral eyes three; spiracles *slit-like*; tail slender.

Type *Buthus cyaneus* of Ceylon. (Pl. LXXXII. fig. 1.)

Subgenus BROTHEAS.

Char. Lamellæ of the pectens few; lateral eyes two or three; spiracles *circular*; tail thick.

Type *Brotheas subnitens*; Peru. (Pl. LXXX. figs. 2, 4, 5, 7, 8, 9, 10, 11, 12.)

[I should expect to find the characters of the genera *Hemiscorpion* and *Opisthophthalmus* of sufficient importance to entitle them to subgeneric recognition.]

Genus 2. TELEGONUS.

Sternum compressed antero-posteriorly, and thus more or less completely divided into laterally expanding narrow lobes or bands.

Subgenera ? (Pl. LXXXII. figs. 4, 5.)

Subfamily II. ANDROCTONINI.

Sternum (metasternite) triangular.

Nerves to the regions of both the first and second pair of lung-books descending from the prosomatic ganglion-mass. The first detached ganglion of the mesosoma lies in its fourth segment, and supplies nerves to the following segment.

Ornament of the lamellæ of the lung-books reticulate as well as punctiform.

A double row of teeth to either both rami of the chelicerae or to the movable ramus only.

Genus unicum. ANDROCTONUS.

Char. of the subfamily.

Subgenus PRIONURUS.

Char. Two rows of teeth to each ramus of the chelicerae; tail very thick; hand rather slender (compared with *Scorpio*).

Types: *Prionurus funestus*, Ehr.: North Africa. (Pl. LXXXII. fig. 2.)

Prionurus occitanus; the yellow Spanish Scorpion.

Subgenus CENTRURUS.

Char. Two rows of teeth to the movable ramus only of the chelicera; a single tooth of a second row present in the fixed ramus sometimes; tail very long and slender, sometimes with a spine below the sting; hand very slender.

Types: *Centrurus americanus*, De Geer. (Pl. LXXXII. figs. 6, 13, 17.)

Centrurus hottentotus: South Africa. (Pl. LXXXII. figs. 7, 11, 18.)

The facts of geographical distribution, so far as they are known, give some importance to the divisions thus recognized. The Scorpions of the Palearctic and Indian regions are essentially those of the genus *Scorpio*. In the Ethiopian region we have both the genera *Scorpio* and *Androctonus*, the latter making its way into Spain, and to some extent into the Indian region.

In America we have both *Scorpio* and *Androctonus*.

The species of the genus *Telegonus* appear to be confined to South America and Tasmania.

I confess to not being at present in a position to offer an opinion upon the questions of species and subgenera in very many cases. It is necessary that all the described forms

should be re-examined, and the really important characters noted and properly drawn. The descriptions and in many cases the figures of authors who have written on Scorpions are, generally speaking, not very intelligible.

The *points* which it seems desirable to note in all cases and to record by enlarged drawings are as follows. I take them in what appears to me to be the order of their importance:—

- I. Form of the sternum, *i. e.* of the dark-coloured chitinized cuticle called metasternite. (Pl. LXXXII. figs. 1 to 7, *a.*)
- II. Arrangement of the nerve-ganglia and innervation of the lung-books. (Woodcut, fig. 2.)
- III. Ornament of the lamellæ of the lung-books. (Pl. LXXXI. figs. 5, 6, 7.)
- IV. Shape of the spiracula.
(This, like the two preceding characters, is one which has not before been made use of. In *Brotheas subnitens* (Pl. LXXX. figs. 9 and 10) the spiracle is circular, a form which has not been previously noticed in Scorpions.)
- V. Dentition of the chelicerae in one or two rows. This is more variable than Peters seems to have thought.
The sharply-cutting denticles of these organs in the Tasmanian *Telegonus* and in *Brotheas subnitens* (comp. figs. 7, 8, Pl. LXXXIII., and figs. 11, 12, Pl. LXXX.) are alike, and differ from the blunter teeth of most other forms here figured.
- VI. Dentition of the chelæ. (Pl. LXXXIII. figs. 21, 22, 23, 24.)
The Scorpionini exhibit fine tubercles, which are disposed *mainly* in a line parallel with the long axis of each ramus; the Androctonini have the straight-line arrangement replaced by a series of short curves.
- VII. Chitinization of the genital operculum, whether in two quite separate plates, as in *Brotheas* (Pl. LXXX. fig. 5), or in one imperfectly divided plate.
- VIII. Proportion of the hand, whether slender, as in Androctonini, or broad, as in Scorpionini.
- IX. Proportions of the whole tail compared to body, both as to length and breadth.
- X. Number of lamellæ and secondary basal teeth on the pectens.
- XI. Position of the central eyes.
- XII. Number and position of the lateral eyes.
- XIII. Keeling or smoothness of the joints of the tail.
- XIV. Proportionate length of the segment preceding the sting.
- XV. Presence of a spine beneath the sting.

EXPLANATION OF PLATES LXXX.-LXXXIII.

PLATE LXXX.

Figs. 1, 2, 3. Dorsal, lateral, and ventral view of the prosoma and mesosoma of an *Androctonus funestus*, in which the venous system has been injected, and is seen showing through the transparent cuticle.

Scs, sinus cephalicus superior; *svsl*, sinus lateralis superficialis of the prosoma; *svsl*¹, sinus lateralis superficialis of the genital (first mesosomatic) segment; *svsl*²-*svsl*⁶, ditto of the second to the sixth mesosomatic segments. In fig. 2 it is seen that the circumpulmonary sinus is placed in continuity with the vein or sinus *svsl*³, *svsl*⁴, *svsl*⁵, and *svsl*⁶, in each of the lung-bearing segments.

Fig. 4. Prosomatic carapace of *Brotheas subnitens*, Gervais: enlarged four diameters.

Fig. 5. Enlarged view of the sternal and pectinal region of *Brotheas subnitens*.

a, the pentagonal metasternite; *b, b*, the two totally separate sclerites of the genital operculum; *c*, median fold; *d*, sternal sclerite of the pectinigerous segment; *e*, pecten.

Fig. 7. Dorsal view of *Brotheas subnitens*, Gervais: magnified twice linear. From a specimen collected by F. Whymper, Esq., in Peru.

Fig. 8. Ventral view of the same specimen.

Fig. 9. Enlarged view of the circular spiracle of *Brotheas subnitens*.

Fig. 10. Toothing of the chela (hand) of *Brotheas subnitens*.

Fig. 11. Toothing of the chelicera of *Brotheas subnitens*; the left-hand figure is the movable ramus.

Fig. 12. View of the rami of the chelicera of *Brotheas subnitens*, to show the cutting-edge as seen from above.

Figs. 13, 14. Plastron or prosomatic entochondrite of *Scorpio (Buthus) cyaneus*, showing the attachment of the muscles. Fig. 13. Dorsal surface. Fig. 14. Ventral surface.

A.C., arterial canal; *G.C.*, gastric canal; *n.c.*, neural canal—only that part of the whole structure *in front of G.C.* and above *n.c.* corresponds to the plastron of *Limulus*; *pf*, posterior flap (unrepresented in *Limulus*); *pp*, posterior process; *lmp*, latero-median process; *ap*, anterior process; *asp*, cornua or anterior tendons of the subneural process; *snp*, the subneural process; *a*, scar of tendinous attachment of the anterior process of the plastron to the horseshoe-shaped "preoral entosclerite," a chitinous epidermal ingrowth really dorsal in nature, though lying ventrally in front

of the mouth. For the muscles referred to by numbers, see the list on p. 359.

Fig. 15. View from below of the pericardium, arteries, pericardio-ventral (veno-pericardiac) muscles, and dorso-ventral muscles of *Androctonus occitanus*. Magnified two diameters, and drawn from an actual dissection.

pp^1 – pp^8 , the series of pericardio-ventral muscles running from the pericardium to the wall of the great ventral vein or sinus of the same side; ar^1 – ar^6 , the lateral arteries of the mesosoma; ar^7 , the lateral artery of the first metasomatic segment; dv^1 – dv^6 , the six dorso-ventral muscles of the mesosoma; dv^7 , the dorso-ventral muscle of the first metasomatic segment.

PLATE LXXXI.

Figs. 1 and 2. Transverse sections of the mesosoma of *Scorpio italicus*, to show the venous blood-spaces and the pericardio-ventral muscles.

alax, axial portion of the alimentary canal; *alc*, glandular cæca of the alimentary canal; *cc*, coagulum within the heart; *cv*, valve and aperture of the heart-wall; *cog*, coagulum in the pericardial blood-space; *cpb*, fibrous bands from heart-wall to pericardium (ventral); *cpu*, similar dorsal bands; *cw*, heart-wall; *dvs*, deep latero-dorsal vein or blood-sinus; *svs*, superficial latero-dorsal vein (same as marked *svsl*¹⁻⁶ in Pl. LXXX. fig. 1); *gc*, genital follicles (testis); *lb*, lamellæ of lung-book; *lm*, longitudinal ventral muscle; *lg*, ventral insertion of dorso-ventral muscle; *ldm*, dorsal longitudinal musculature; *n*, nerve-cord; *pvs*, pericardial blood-space; *ppm* (in fig. 2), the pericardio-ventral or pericardio-pulmonary or veno-pericardiac muscles passing from the pericardium to the roof of the circumpulmonary blood-sac; *ps*, the circumpulmonary blood-sac; *spa*, supramedullary artery of Newport.

Figs. 3 and 4. Transverse sections of the lamellæ of the lung-books of *Androctonus funestus*, showing the blood-spaces, B, containing blood-corpuscles, *bc*, and traversed by short cell-columns, *cc* (as in *Limulus*), and the air-spaces, A, on the lining of which the cuticle is roughened (ornate).

In fig. 3 the drawing is inverted since the points *yy* are the free ends of lamellæ, which stand upwards into the blood-space, the spaces between these air-holding lamellæ being open to the blood-current.

In fig. 4 the section passes through a region where the ends of the air-holding lamellæ are fused to the wall of the circumpulmonary blood-sinus and to one another by the tissue *x*.

Fig. 5. Reticular ornament from the air-bathed surface of a lung-lamella of *Androctonus funestus*, near the centre of the lamella.

Fig. 6. Similar structure combined with punctate ornament from the periphery of the same lamella.

Fig. 7. Simple punctate ornament of the lung-lamellæ of *Scorpio* (*Buthus*) *cyaneus*.
Seen also in *Euscorpius italicus*, in *Brotheas subnitens*, and in *Telegonus*, sp.

PLATE LXXXII.

Figs. 1, 2, 3. Complete ventral surface and limbs of *Buthus cyaneus*, *Prionurus funestus*, and *Euscorpius italicus*.

Fig. 4. Sternal region of *Telegonus*, sp., from Coquimbo (British Museum).

Fig. 5. Ditto ditto, from Tasmania (British Museum).

Fig. 6. Ditto of the common American and West-Indian *Centrurus* (*C. americanus*).

Fig. 7. Ditto of the common African *Centrurus* (*C. hottentotus*).

Fig. 8. Lateral eyes of the Tasmanian *Telegonus*.

Fig. 9. Ditto of *Euscorpius italicus*.

Fig. 10. Ditto of *Buthus cyaneus*.

Fig. 11. Ditto of *Centrurus hottentotus*.

Fig. 12. Ditto of the *Telegonus* from Coquimbo.

Fig. 13. Ditto of *Centrurus americanus*.

Fig. 14. Ditto of *Prionurus funestus*.

Figs. 15-21. Sting and last tail-segment of species of Scorpions as marked on the Plate.

PLATE LXXXIII.

Figs. 1 to 12. Chelicerae: movable (*m*) and fixed (*f*) rami being placed side by side, of various species of Scorpions as indicated on the Plate.

a in one ramus indicates the margin which works against *a* in the other.

Fig. 13. Liver (gastric gland) of *Androctonus* (*Prionurus*) *funestus*. *a*, anterior division, more branched, sometimes distinguished by the name "salivary gland"; *b*, compact, slightly fissured, main mass of the gland. Nat. size.

Fig. 14. Liver (gastric gland) of *Euscorpius italicus*, Roes. Letters as in fig. 13. Magnified five diameters.

Figs. 15-20. Prosomatic tergite of various Scorpions, indicated by name on the Plate.

Figs. 21-24. Toothings of the fixed (*f*) and movable (*m*) rami of the chelæ of four species of Scorpion.

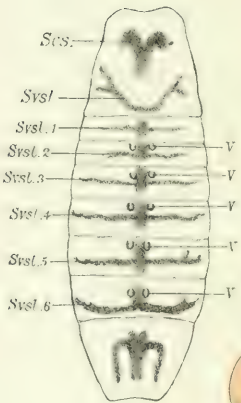


Fig. 1.



Fig. 4.

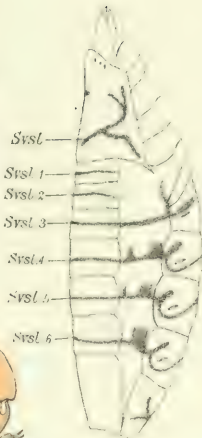


Fig. 2.

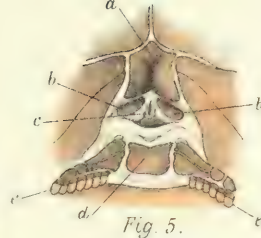


Fig. 5.



Fig. 3.



Fig. 6.

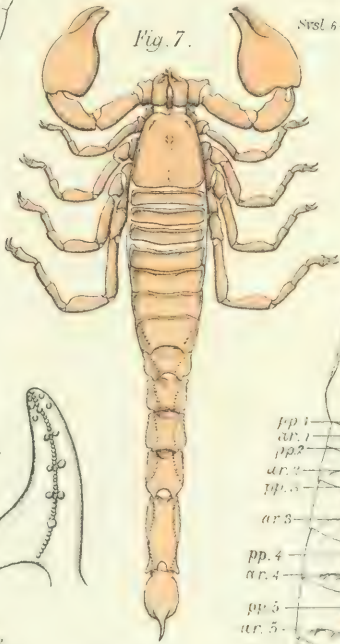


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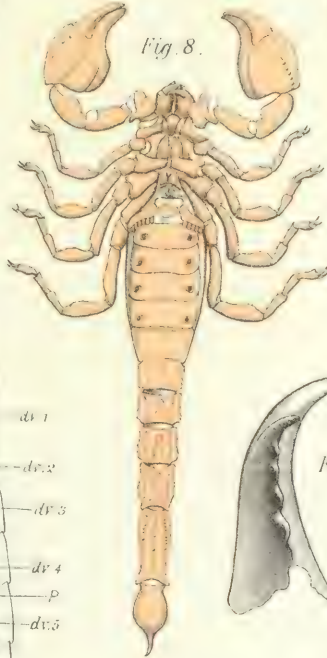


Fig. 8.



Fig. 9.

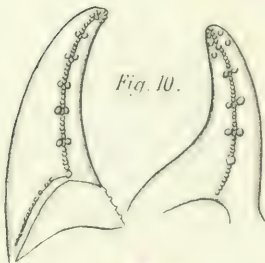


Fig. 10.

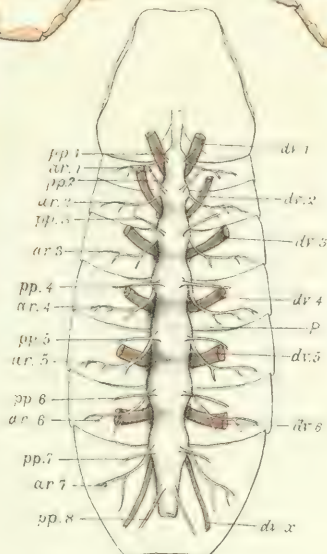


Fig. 15.

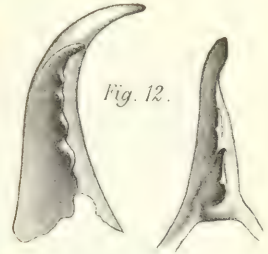


Fig. 12.

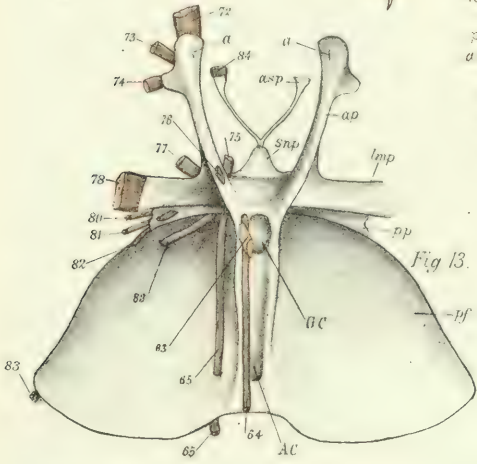


Fig. 13.



Fig. 11.

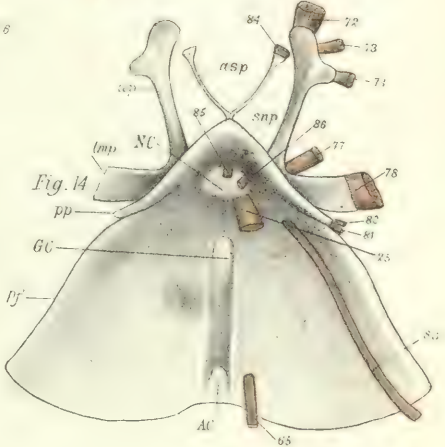


Fig. 14.

E. Ray Lankester del.

C. Berjeau lith.

ANATOMY OF SCORPIO.

Hatched, asp.

Fig. 4.

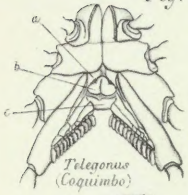
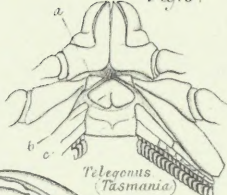
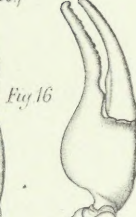
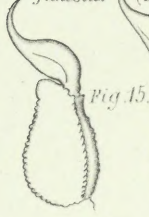


Fig. 5.



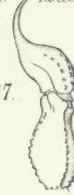
Androctonus funestus Telegonus (Coquimbo)



Androctonus Americanus.



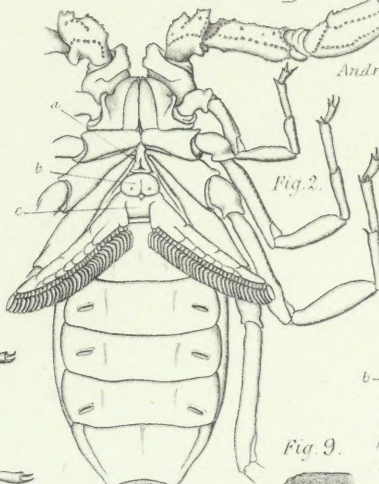
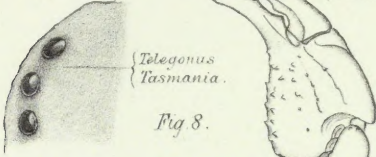
Androctonus hollenotus.



Sc. Cyanus.



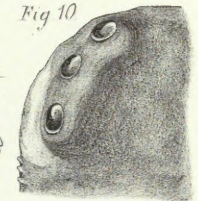
Fig. 8.



Androctonus funestus.

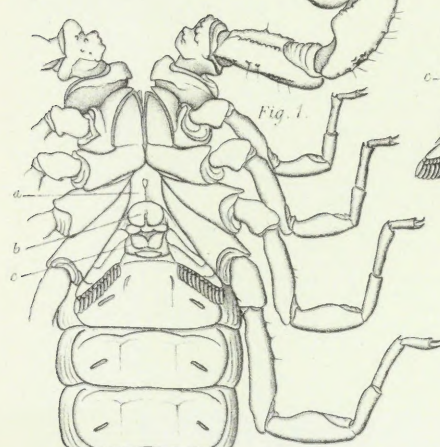
Fig. 3.

Scorpio Italicus



Sc. cyanus

Fig. 1.



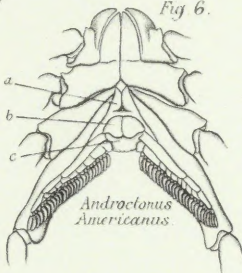
Sc. cyanus

Fig. 9.



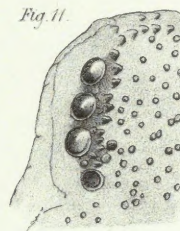
Sc. Italicus.

Fig. 6.



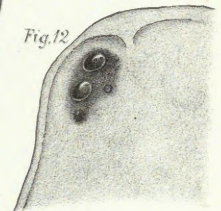
Androctonus Americanus

Fig. 11.



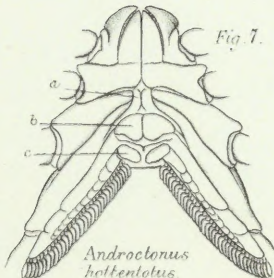
Androctonus hollenotus

Fig. 12.



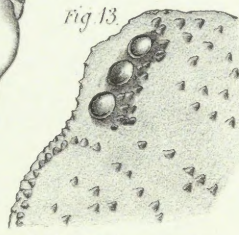
Telegonus (Coquimbo.)

Fig. 7.



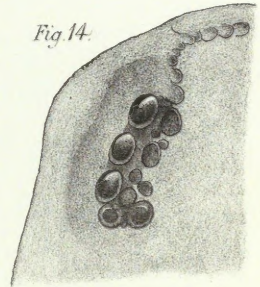
Androctonus hollenotus.

Fig. 13.



Androctonus americanus

Fig. 14.



Androctonus funestus.

Hanhart imp.

Sc. Italicus ♂

Fig. 20.

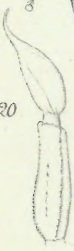


Fig. 21.

